State of New York—Department of Agriculture

TWENTY-EIGHTH ANNUAL REPORT

OF THE

BOARD OF CONTROL

OF THE

NEW YORK

Agricultural Experiment Station

(GENEVA, ONTARIO COUNTY)

FOR THE YEAR 1909

With Reports of Director and Other Officers

TRANSMITTED TO THE LEGISLATURE JANUARY 15, 1910.

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STATE OF NEW YORK

No. 25.

IN ASSEMBLY

JANUARY 15, 1910.

TWENTY-EIGHTH ANNUAL REPORT

OF THE

BOARD OF CONTROL OF THE NEW YORK AGRICULTURAL EXPERIMENT STATION.

STATE OF NEW YORK:
DEPARTMENT OF AGRICULTURE.
ALBANY, N. Y., *January* 15, 1910.

To the Assembly of the State of New York:

I have the honor to herewith submit the Twenty-eighth Annual Report of the Director and Board of Control of the New York Agricultural Experiment Station at Geneva, N. Y., in pursuance of the provisions of the Agricultural Law.

I am, respectfully yours,

RAYMOND A. PEARSON,
Commissioner of Agriculture.

NEW YORK AGRICULTURAL EXPERIMENT STATION.

GENEVA, N. Y., *January* 1, 1910.

HON. RAYMOND A. PEARSON, *Commissioner of Agriculture, Albany, N. Y.:*

DEAR SIR.— I have the honor to transmit herewith the report of the Director of the New York Agricultural Experiment Station for the year 1909, in accordance with the provisions of chapter 439, Laws of 1904.

Yours respectfully,

T. B. WILSON,

President, Board of Control.

ORGANIZATION OF THE STATION 1909.

BOARD OF CONTROL.

GOVERNOR CHARLES E. HUGHES, Albany.
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LYMAN P. HAVILAND, Camden.
EDGAR G. DUSENBURY, Portville.
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IRVING ROUSE, Rochester.
ALFRED G. LEWIS, Geneva.
LEWIS L. MORRELL, Kinderhook.
ELIHU S. MILLER, Wading River.

OFFICERS OF THE BOARD.

THOMAS B. WILSON, *President.*

WILLIAM O'HANLON, *Secretary and Treasurer.*

STATION STAFF.

WHITMAN H. JORDAN, Sc.D., LL.D., *Director.*

GEORGE W. CHURCHILL, *Agriculturist and Superintendent of Labor.*
WILLIAM P. WHEELER, *First Assistant (Animal Industry).*
FRED C. STEWART, M.S., *Botanist.*
JOHN G. GROSSENBACHER, PD.B., A.B. *Associate Botanist.*
[1]G. TALBOT FRENCH, B.S.,
[2]STOCKTON M. MCMURRAN, B.S., *Assistant Botanists.*
LUCIUS L. VAN SLYKE, PH.D., *Chemist.*
ALFRED W. BOSWORTH, B.S.,
ERNEST L. BAKER, B.S., *Associate Chemists.*
ARTHUR W. CLARKE, B.S.,
ANTON R. ROSE, B.S.,
MORGAN P. SWEENEY, A.M.,
JAMES T. CUSICK, B.S.,
OTTO MCCREARY, B.S., *Assistant Chemists.*
HARRY A. HARDING, M.S., *Bacteriologist.*
MARTIN J. PRUCHA, M.S., *Associate Bacteriologist.*
JAMES K. WILSON, B.S., *Assistant Bacteriologist.*
GEORGE A. SMITH, *Dairy Expert.*
FRANK H. HALL, B.S., *Editor and Librarian.*
PERCIVAL J. PARROTT, M.A., *Entomologist.*
HAROLD E. HODGKISS, B.S.,
[1]WILLIAM J. SCHOENE, B.AGR., *Assistant Entomologists.*
ULYSSES P. HEDRICK, M.S., *Horticulturist.*
RICHARD WELLINGTON, B.S.,
MAXWELL J. DORSEY, B. S.,
W. H. ALDERMAN, B.S.AGR., *Assistant Horticulturists.*
ORRIN M. TAYLOR, *Foreman in Horticulture.*
[3]WM. J. YOUNG, B.S., *Student Assistant in Horticulture.*
[4]F. ATWOOD SIRRINE, M.S., *Special Agent.*
[5]JENNIE TERWILLIGER, *Director's Secretary.*
FRANK E. NEWTON,
WILLARD F. PATCHIN,
[6]CORA A. WHITAKER,
[7]MAY A. DURKIN,
[8]LENA G. CURTIS, *Clerks and Stenographers.*
ADIN H. HORTON, *Computer and Mailing Clerk.*
[9]JULIA H. HOEY, *Junior Clerk.*
[10]DONALD REDDICK, Ph.D., *Assistant Botanist.*
[10]F. Z. HARTZELL, M.A., *Assistant Entomologist.*
[10]F. E. GLADWIN, B.S., *Special Agent.*

Address all correspondence, not to individual members of the staff, but to the NEW YORK AGRICULTURAL EXPERIMENT STATION, GENEVA, N. Y.

The Bulletins published by the Station will be sent free to any farmer applying for them.

[1] Absent on leave after October 1.
[2] Appointed October 1.
[3] From June 1 to September 15.
[4] Riverhead, N. Y.
[5] Absent on leave up to December 1.
[6] Resigned December 1.
[7] Appointed October 1.
[8] Appointed December 1.
[9] Resigned October 10.
[10] Connected with Chautauqua Grape Investigations.

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Twenty-Eighth Annual Report

OF THE

Board of Control of the New York Agricultural Experiment Station.

TREASURER'S REPORT.

Geneva, N. Y., *October* 1, 1909.

To the Board of Control of the New York Agricultural Experiment Station:

As Treasurer of the Board of Control, I respectfully submit the following report for the fiscal year ending September 30, 1909:

Maintenance Fund — Necessary Expense.

APPROPRIATION 1908–1909.

Receipts.

1908.			*Dr.*
Oct.	1.	To balance on hand..................	$93 98
		To amount received from Comptroller.	20,000 00
			$20,093 98

		Expenditures.	*Cr.*
		By building and repairs.............	$615 77
		By chemical supplies...............	1,250 52
		By contingent expenses.............	2,231 34
		By feeding stuffs	1,186 75
		By fertilizers......................	236 75
		By freight and express..............	727 06
		By furniture and fixtures............	67 00
		By heat, light and water............	840 92
		By library	970 49
		By live stock.......................	138 00
		By postage and stationery...........	1,647 11
		By publications	4,777 44
		By scientific apparatus..............	154 58
		By seeds, plants and sundry supplies.	2,529 53
		By tools, implements and machinery..	518 35
		By traveling expenses..............	2,177 59
1909.			
Oct.	1.	By balance	24 78
			$20,093 98

GENERAL EXPENSE — HEAT, LIGHT, WATER, ETC.

APPROPRIATION 1908–1909.

		Receipts.	
1908.			*Dr.*
Oct.	1.	To balance on hand	$294 95
		To amount received from Comptroller.	4,000 00
			$4,294 95

		Expenditures.	*Cr.*
		By building and repairs.............	$2,139 81
		By freight and express..............	48 45
		By heat, light and water............	1,757 35
		By scientific apparatus	314 72
1909.			
Oct.	1.	By balance	34 62
			$4,294 95

SPECIAL FUND — HORTICULTURAL INVESTIGATIONS.

APPROPRIATION 1908–1909.

		Receipts.	
1908.			*Dr.*
Oct.	1.	To balance on hand................	$82 09
		To amount received from Comptroller.	8,000 00
			$8,082 09

		Expenditures.	*Cr.*
		By contingent expenses	$307 27
		By postage and stationery..........	170 00
		By publications	213 46
		By salaries	6,893 15
		By seeds, plants and sundry supplies .	23 60
		By traveling expenses	95 94
1909.			
Oct.	1.	By balance	378 67
			$8,082 09

SALARIES.

1908–1909.

Receipts.

			Dr.
1908.			
Oct.	1.	To balance on hand	$581 98
		To amount received from Comptroller	31,000 00
			$31,581 98

		Expenditures.	*Cr.*
		By salaries	$31,312 58
1909.			
Oct.	1.	By balance	269 40
			$31,581 98

LABOR.

1908–1909.

Receipts.

			Dr.
1908.			
Oct.	1.	To balance on hand	$291 60
		To amount received from Comptroller	13,000 00
			$13,291 60

		Expenditures.	*Cr.*
		By labor	$13,029 26
1909.			
Oct.	1.	By balance	262 34
			$13,291 60

FERTILIZER INSPECTION.

1908–1909.

Receipts.

			Dr.
1908.			
Oct.	1.	To balance	$3,951 75
		To amount received from Comptroller	8.500 00
			$12,451 75

		Expenditures.	Cr.
		By chemical supplies	$1,106 16
		By contingent expenses	1 00
		By freight and express	58 32
		By heat, light and water	420 10
		By postage and stationery	50
		By publications	1,091 65
		By salaries	7,972 21
		By scientific apparatus	144 50
		By traveling expenses	95 01
1909.			
Oct.	1.	By balance	1,562 30
			$12,451 75

CONCENTRATED FEEDING STUFFS INSPECTION.

1908–1909.

Receipts.

			Dr.
1908.			
Oct.	1.	To balance	$577 15
		To amount received from Comptroller	3,500 00
			$4 077 15

		Expenditures.	*Cr.*
		By chemical supplies	$112 50
		By freight and express	28 41
		By heat, light and water	107 60
		By publications	733 44
		By salaries	2,409 95
1909.			
Oct.	1.	By balance	685 25
			$4,077 15

CHAUTAUQUA GRAPE WORK.

Receipts.	*Dr.*
To amount received from Comptroller	$1,270 91

Expenditures.	*Cr.*
By building and repairs	$14 05
By chemical supplies	23 95
By contingent expenses	1 00
By fertilizers	21 80
By freight and express	3 41
By furniture and fixtures	30 00
By heat, light and water	40
By labor	9 63
By postage and stationery	2 80
By salaries	550 00
By scientific apparatus	166 09
By seeds, plants and sundry supplies	220 58
By tools, implements and machinery	8 62
By traveling expenses	218 58
	$1,270 91

DWELLING HOUSES.

1908–1909.

Receipts.	*Dr.*
To amount received from Comptroller	$31,519 72

Expenditures.	*Cr.*
By buildings	$31,519 72

ELECTRICAL WORK.

1908–1909.

Receipts.	*Dr.*
To amount received from Comptroller	$2,330 90

Expenditures.	*Cr.*
By electrical work................	$2,330 90

CATTLE SHEDS.

1908–1909.

Receipts.	*Dr.*
To amount received from Comptroller	$1,598 87

Expenditures.	*Cr.*
By construction	$1,598 87

POULTRY HOUSE.

APPROPRIATION 1908–1909.

Receipts.	*Dr.*
To amount received from Comptroller	$1,199 89

Expenditures.	*Cr.*
By construction	$1,199 89

UNITED STATES APPROPRIATIONS.

1908–1909.

HATCH FUND.

Receipts.	*Dr.*
To receipts from the Treasurer of the United States as per appropriation for fiscal year ended June 30, 1909, as per act of Congress approved March 2, 1887	$1 500 00

Expenditures.	*Cr.*
By salaries	$222 53
By labor	1,145 33
By publications	132 14
	$1,500 00

ADAMS FUND.

APPROPRIATION 1908–1909.

Receipts.	*Dr.*
To receipts from Treasurer of the United States as per appropriation for fiscal year ended June 30, 1909.	$1,100 00

Expenditures.	*Cr.*
By salaries	$1,100 00

All expenditures are supported by vouchers approved by the Auditing Committee of the Board of Control and have been forwarded to the Comptroller of the State of New York.

(Signed) W. O'HANLON,
Treasurer.

DIRECTOR'S REPORT FOR 1909.*

To the Honorable Board of Control of the New York Agricultural Experiment Station:

GENTLEMEN.— I have the honor to submit herewith for your consideration a report of the condition and work of this institution for the year 1909. In this connection I take the liberty of presenting a statement of the additional funds and equipment which I regard as essential to the continued progress and efficiency of the Station as an agency for the advancement of New York Agriculture. Suggestions are also offered as to the proper function of an experiment station in promoting the welfare and prosperity of the farming class.

ADMINISTRATION.

STATION STAFF.

A most gratifying continuity of service by the members of the Station Staff now exists. During the year now ending no changes in the staff have occurred excepting that Stockton M. McMurran, B. S., was appointed as Assistant Botanist to assume temporarily the duties of a member of the botanical staff now absent for the purpose of further study.

MAINTENANCE FUNDS.

The funds available for the support of the Station for the fiscal year beginning October 1, 1909, are as follows:

Salaries	$40,000
Labor	15,000
Maintenance and distribution of scientific work of Station departments	22,500
General expense, heat, light, repairs, etc	5,500
Total	$83,000

* A reprint of Bulletin No. 321.

Expense of work required by Commissioner of Agriculture.

Fertilizer inspection	$10,000
Feeding stuff inspection	3,500
Total	$13,500

By order of your Board the following appropriations are to be requested of the Legislature of 1910, for the support of the Station for the fiscal year beginning October 1, 1910.

For the general maintenance of the Station:

Salaries	$47,000
Labor	15,800
Maintenance and distribution of scientific work of Station departments	22,500
General expense, heat, light, repairs, etc	5,500
Total	$90,800

Expense of work required by the Commissioner of Agriculture:

Fertilizer inspection	$10,000
Feeding stuff inspection	3,500
Total	$13,500

The above items are similar to those allowed by the Legislature of 1909 excepting that $7,000 more is asked for salaries and $800 more for labor.

An addition to the salary item appears to be demanded by conditions over which the management of the Station has no control. On account of the competition among agricultural colleges and experiment stations in securing the services of well equipped and experienced teachers and investigators the maintenance of an efficient staff at the Station has assumed a somewhat critical stage. Persons competent to serve these institutions efficiently are not being trained in numbers proportional to the rapid increase of funds that are set aside for agricultural education and research; and other institutions now receiving increases of federal and state support, in seeking to enlarge their staffs, are offering larger salaries than the leading members of the Station Staff are

now receiving. In order to retain these men, whose places could be filled only at higher salaries, and with difficulty even then, it seems imperative that their compensation be increased. The efficiency of any institution is measured by the efficiency of its men. After a careful consideration of the whole question it was decided that the additional sum of $7,000 will be needed to maintain the Station Staff on its present basis.

The increased rates of wages and the enlarging equipment and activities of the Station are requiring a larger labor fund and it is estimated that a minimum increase to this fund of $800 will be needed for the next fiscal year.

STATION PUBLICATIONS.

The following is an approximately accurate statement of the number of names on the Station mailing lists at the present time to which Station bulletins are sent:

POPULAR BULLETINS.

Residents of New York	37,155
Residents of other states	2,730
Newspapers	770
Experiment stations and their staffs	1,481
Miscellaneous	100
Total	42,236

COMPLETE BULLETINS.

Experiment stations and their staffs	1,481
Libraries, scientists, etc.	200
Foreign list	276
Individuals	3,700
Miscellaneous	100
Total	5,760

Early in 1909 the publication known as "The Grapes of New York," being Part II of the Station Report for 1907, became available for distribution. Nine thousand copies were printed, of which two thousand were assigned to this institution. There is an active demand for this work, not only in New York but throughout the United States, and the supply does not meet the demand for even our own State. Requests for "The Apples of

New York," the distribution of which was begun in 1904, are still being made in considerable numbers, many of which cannot be met.

The third publication in the series, "The Plums of New York" is now in preparation and the copy will be submitted as a part of the Station Report for 1910.

REPAIRS.

By the use of a special appropriation of $2,500 granted by the Legislature of 1909, all of the Station buildings excepting the new houses have been painted and numerous other needed repairs have been made. Before long quite an extensive renovation should be given to the Chemical Laboratory which has had little attention since its erection in 1891–2.

ELECTRICAL EQUIPMENT.

Since the opening of the year the Station has become equipped for the use of electricity as a motor power and for lighting. Motors are now used for running the refrigerating plant, the mills for grinding samples in the Chemical Laboratory, and the milking machine; and the main buildings, including the stables, are thoroughly equipped with electric lights.

A BUILDING NEEDED FOR ADMINISTRATIVE AND DEMONSTRATION PURPOSES.

The Legislature of 1909 appropriated $40,000 for the erection at the Station of a new building to be used mainly for the purposes of administration and demonstration. This sum was $20,-000 less than was asked for this purpose. The Governor felt the necessity of disallowing this item and so it is necessary to again make an appeal for the funds necessary for the erection of the proposed structure.

The reasons why this building is needed have been fully presented in two previous reports, a brief abstract of which is given in this connection:

(1) The building, formerly a dwelling house, now occupied for administration purposes should be devoted to caring for unmarried members of the Station Staff who now must procure their meals at a mile or mile and a half distance from the Station. Administrative quarters should, therefore, be provided elsewhere.

(2) The Station is greatly in need of space in which to make an objective display of the results it has reached.

(3) There is no place at the institution where even a small audience can be assembled excepting out of doors in pleasant weather.

For a fuller statement of the above considerations reference is made to the Station Reports for 1907 and 1908.

INVESTIGATIONS IN THE INTEREST OF GRAPE GROWING IN CHAUTAUQUA COUNTY.

The Legislature of 1909, by special enactment, appropriated $10,000 for the purpose of inaugurating an extended study of the conditions attending grape growing in Chautauqua County. This action was taken without solicitation on the part of the Station authorities at the earnest request of a large body of grape growers. The reason assigned for this demand for help was that the vineyards of western New York appeared to be suffering a marked drop in condition and productiveness, brought about undoubtedly by a combination of causes such as bad methods of culture, unfavorable moisture conditions and the serious ravages of fungus and insect pests. It was the belief of the grape growers themselves that some underlying hidden influences were menacing the vineyards and that the industry which is the sole dependence of many of them was in danger of being destroyed, but in view of the satisfactory crop of 1909 such a view is hardly tenable. It is more rational to conclude that a combination of known causes which for a few years operated in unusual numbers and with unusual severity is the explanation of the decreased output of grapes.

In obedience to legislative action the work of inquiry into vineyard problems has been organized in Chautauqua County. Thirty acres of land near Fredonia on which are twenty acres of vineyard, have been leased for a period of years, and temporary facilities have been established in connection therewith for carrying on the necessary laboratory studies.

The following persons have been employed in addition to the regular Station Staff to carry on the necessary studies:

Fred E. Gladwin, A. B., Special Agent.

Donald Reddick, Ph. D., in plant pathology.

Fred Z. Hartzell, M. A., in entomology.

Cultural experiments to extend over a series of years have been begun in the leased vineyard, and studies of fungus and insect pests have been inaugurated. During the past summer records were secured of the past and present conditions existing in not less than 75 per ct. of all the vineyards in the grape belt. It is expected that another season experiments and observations on fungus and insect pests will be considerably extended to those localities that offer good opportunities for such studies.

THE RELATION OF THE STATION TO THE EXTENSION OF AGRICULTURAL KNOWLEDGE.

There is now in progress a notable movement for the extension of knowledge among the agricultural people of the United States. This movement, which had its small beginnings more than a half century ago and has now developed to great magnitude, is taking several forms, the principal ones of a popular nature being farmers' institutes, bulletins, reading courses and other literature issued by the United States Department of Agriculture, agricultural colleges and experiment stations, demonstration work on individual farms, exhibits at fairs, addresses before agricultural bodies and personal advice to farmers by correspondence or visitation. In certain sections of the United States so called demonstration farms have been established. At least twenty-five of the

agricultural colleges have established extension departments and at the last convention of the Association of Agricultural Colleges and Experiment Stations, the constitution of the Association was amended to provide for a section to be devoted to the consideration of extension work. It is practically certain that Congress will be asked to further endow the agricultural colleges in order that these institutions may greatly enlarge their activities in the popular education of the agricultural masses. All of this effort has for its purpose, of course, the promotion of larger intelligence on the part of farmers and, as a consequence, a higher and more productive type of agriculture.

Recently several gentlemen prominent in industrial affairs have wisely and opportunely discussed in a public way the economic future of this country from the standpoint of its agricultural efficiency. They have called attention to the low yield of staple products in many parts of the United States, to the approaching balance between our production of food stuffs and our home needs and point to the time when, unless our agricultural methods improve, we will not produce the bread we consume.

It is undoubtedly true that the maximum productive capacity of the farms in the older states has not been maintained, even approximately. It is equally true that by proper methods the fertility of run-down farms may be restored and through better farm practice the average acreage production increased in New York by a large percentage, even doubled. Granting, then, the economic necessity of better farming and the possibility of attaining it, we are confronted with the question as to how this is to be brought about and what relation this institution has to the effort.

Long association with the effort of agricultural betterment generally convinces an intelligent observer that the practice on any given farm will not rise above the level of the farmer's capacity and intelligence, and that even in our most prominent agricultural states there are thousands of farms where improved methods may not reasonably be expected because the owners are

not susceptible to improvement themselves. This is the type of man who for several decades has withstood the appeals that have been made to his intelligence and business sense through agricultural literature, farmers' institutes, the example of successful neighboring farms and other influences, direct and indirect. It is urged by several prominent men, whose advice is not to be ignored, that so called model or demonstration farms be established at public expense in perhaps every county in the older states as a sure means of rescuing our agriculture from its alleged low state through the educational influence of observation and the power of example. This question cannot be discussed at length in this connection but it may well be remarked that such a scheme is almost certain to prove very disappointing. Official farming in such an extensive way would be precarious on the practical side, it would certainly be very expensive if a farm was equipped to demonstrate along all lines of agriculture important to even a single county, and there are grave reasons for believing that official success would have less influence than private success. There are thousands of farms in New York on which it is being demonstrated that generous and profitable crops may be grown, the lessons from which pass unheeded by many other neighboring farmers. Many who have had experience in the field of agricultural education in its various forms are convinced that the establishment of model farms is unwise and that the most effective demonstrations are those made on private farms, as opportunity offers for teaching a lesson important to a given locality. This plan permits the adaptation of the work to changing needs and a great variety of conditions, and involves less expense and less danger of failure than the equipment of permanent extensive establishments. But admitting, as we should, that such demonstrations may be effectively educational, it is still true that the future of agriculture will be determined by the slow processes of education that operate principally on the growing generation. We must depend upon the training and development of a type of man and not upon panaceas.

What place has the experiment station in this educational work? There seems to be a general expectation on the part of the public that an experiment station is to participate in all forms of agricultural teaching outside of school or college instruction. There exists a widespread and insistent public demand that members of the Station Staff engage in the various forms of extension teaching at institutes, from the convention platform, by means of literature and as a correspondence bureau, a demand which constitutes a real and perplexing problem for those who are attempting investigation of agricultural problems in a way that requires concentration and continuity of effort.

The work of an experiment station relates primarily to the acquisition of knowledge rather than to its dissemination. All teaching, whether academic or popular, indeed, all farm practice, must rest upon a body of knowledge that should be scientific and reliable, which it is the function of an experiment station to enlarge. Agriculture now suffers from the limitations of knowledge as well as from so-called science that is utterly unreliable, and no more essential or useful service can be rendered to the farmer and to the public in general than the discovery of new truth that makes possible greater efficiency and economy in farm management. Inquiry must precede instruction of all forms, from the college class room to educational efforts of the most popular kind, and it is a serious mistake to so dissipate the energies of agricultural investigators as to render them inefficient in the peculiar field to which they are assigned.

In 1907 the Association of American Agricultural Colleges and Experiment Stations appointed a commission to consider and report on the conditions that should surround the effort at agricultural research in the United States. This Commission found that a large amount of publicity work had been required of those persons holding positions of scientific responsibility in agricultural colleges and experiment stations, thereby greatly minimizing the efficiency of the agencies that are established for agricul-

tural research. On this point, and in relation to freeing the investigator from hampering conditions the Commission made the following statements:

"The progress of agricultural knowledge now demands that agricultural research agencies shall deal as largely as possible with fundamental problems, confining attention to such as can be adequately studied with the means available."

"The work of research in agriculture should be differentiated as fully as practicable, both in the form of organization and in the relations of the individual investigator, from executive work, routine teaching, promotion and propaganda, and should be under the immediate direction of an executive trained in the methods of science who should not be hampered by other duties of an entirely unlike character."

"The investigator should be free from all coercion whatever. In reaching his conclusions he should be equally free from the prescription of received opinion and the temptation to exploit his results for the purpose of obtaining future support. To this end, his work should be as far removed from immediate dependence upon legislation as is consistent with due responsibility to the public, and his relations to the public and to the organization of which he is a member should be such as to promote individual initiative and not interfere with freedom of conclusion or utterance on scientific questions."

REVIEW OF THE YEAR'S WORK.

DEPARTMENT OF BACTERIOLOGY.

Inoculation and lime as factors in growing alfalfa.— The object of the co-operative experiments reported in Bulletin 313 was to get a measure of the real need of inoculation and of lime in connection with the growing of alfalfa on the farms of this State, and, so far as possible, to determine the relative importance of these lines of treatment in connection with the growing of this crop.

The results from more than 100 co-operative experiments in growing alfalfa, located in over one-half of the counties of the State, indicate that where neither lime nor inoculation is applied the chance of a successful crop is not more than 20 per ct., or one chance in five. Where lime is added to the land at the rate of 1,500 pounds per acre the chance of success is raised to about 60 per ct., or about three chances out of five. Where both lime and inoculation are applied as above directed the chance of a successful crop is raised to about four out of five.

Each farmer intending to try the growing of alfalfa should restrict his seeding to a single acre and so arrange that acre as to determine what line of treatment is required by his field.

These results, obtained during 1905-08, were rendered possible only through the active co-operation of approximately 200 farmers.

Milking machines.— The perfection of a mechanical cow milker would be a more important advance in dairying than has occurred since the introduction of the centrifugal cream separator.

For the past three years milking machines have been in use in the Station dairy and some of our observations are given in Bulletin 317. These are confined to the effect of methods of handling the machines upon the germ content of the milk.

Where the machines were given only a good washing each day the milk had a very high germ content and soured quickly. Keeping the rubber parts of the machine in a 10 per ct. salt solution between milkings markedly reduced the germ content. When the machines were provided with sufficiently large air filters and these were properly filled with cotton the germ content was still further reduced. When both of these matters were attended to and the machines were handled carefully in all respects the germ content of the milk compared favorably with that ordinarily obtained under similar barn conditions.

Bacterial soft rots of certain vegetables.— The common vegetables are often subject to soft rots which are of considerable

economic importance, particularly in the cabbage and cauliflower industry of Long Island. For some years certain of these rots have been studied jointly at this Station and the Vermont Agricultural Experiment Station and the results of a part of this study are given in Technical Bulletin 11. The first part of the bulletin shows that the organisms are identical and the second part describes the bacterial enzyms by means of which the bacteria destroy the plant tissue.

DEPARTMENT OF BOTANY.

Potato spraying experiments.—During the season of 1908 the potato spraying experiments begun in 1902 were continued along the same lines as in previous years. The results have been published in Bulletin 311. In the ten-year experiment at Geneva six sprayings increased the yield 39 bu. per acre, while three sprayings increased it 29.5 bu. In the duplicate of this experiment at Riverhead, Long Island, the gain due to five sprayings was 15.3 bu. per acre and to three sprayings 10.75 bu. In fourteen farmers' business experiments, including 200 acres, the average gain due to spraying was 18.5 bu. per acre; the average total expense of spraying was $4.30 per acre and the average net profit $8.53 per acre. Eleven volunteer experimenters reported gains averaging 66.3 bu. per acre.

Thus far the results are highly favorable to the practice of spraying. In the ten-year experiments at Geneva the average gain for seven years from spraying every two weeks has been 110 bu. per acre, and from spraying three times during the season, 84 bu. At Riverhead the corresponding gains have been smaller — 54 and 29.3 bu. respectively. In 76 business experiments made in six years the average gain due to spraying has been 43.8 bu. per acre and the average net profit from spraying $17.94 per acre. In 188 volunteer experiments reported in five years the average gain from spraying was 50.5 bu. per acre.

A Mycosphærella wilt of melons.— The muskmelons in one of the Station greenhouses were much damaged during 1907–8 by an uncommon disease. The vines were parasitized by a fungus (Mycosphærella) shortly before the earliest melons were ripe. The disease was preceded, in both instances, by the attacks of a red spider, though in 1908 the damage by the spiders was but slight. The fungus is reported as causing a disease of several cucurbits in the fields in some parts of Delaware, but had never been recorded for this State. Since the Delaware reports differed in some respects from the observations made at this Station in 1907, nothing was published till further information could be obtained on the points of difference. The observations were repeated and extended in 1908.

The pathogeneity of the fungus and the relation of its two spore-forms are established. Inoculation experiments were effective, and, with but a few exceptions, the spore-forms of the fungus always appeared successively on the inoculated vines.

Though this disease has recently been found destructive in several of the southeastern States, it is seemingly harmful only in melon greenhouses of this State. For a fuller report see Technical Bulletin 9.

Crown-rot, arsenical poisoning and winter-injury.—Crown-rot has been attributed to parasitic organisms, to arsenical poisoning and also to low temperature. From the available literature reviewed and from recent observations (though there are many contradictions) there seems little doubt about its being due to low temperatures, primarily. But the relation of the main secondary factors, such as the type of soil, soil moisture, stock-scion relations, and wood-maturity, to each other and to the primary cause, need investigation; and as a consequence proper preventive measures, based upon general principles cannot be formulated, but long expensive tests must be made to determine these matters for each locality.

A fuller account is found in Technical Bulletin 12.

DEPARTMENT OF CHEMISTRY.

A simple casein test.— There has long been a need for some simple and rapid method by which the amount of casein in milk can be determined. Such a method has been finally worked out in our chemical department. The method can be readily used by any one who is accustomed to the determination of acidity of cream at creameries or of whey at cheese factories. It calls for simple apparatus only and involves the use of no complicated, expensive machinery. The method will find extensive application in dairy schools, in all investigations of milk calling for casein determinations, at cheese factories, where, in case of abnormal milk, as in times of drouth, it is desirable to know the amount of casein in order to make cheese to best advantage. This test is described in Technical Bulletin 10.

A chemical study of lime-sulphur washes.— This investigation was undertaken to solve some of the difficulties which fruit growers have met in making and using lime-sulphur washes. Conditions of preparation were studied and also the composition of commercial washes. The results, as given in Bulletin 319, indicate that a concentrated preparation can be best made by using 125 pounds of sulphur, 60 pounds of lime of best commercial quality and water enough to make 50 gallons, the whole to be boiled about 60 minutes. The presence of magnesium oxide in lime is a serious detriment, since it causes loss of sulphur by producing hydrogen sulphide gas, which is also poisonous and may affect uncomfortably persons who are near the boiling mixture for any length of time. The addition of lime to a diluted wash causes marked chemical changes which affect seriously the insecticidal value of the wash. The commercial preparations examined varied considerably in composition. One brand contained considerable sediment, for which peculiar insecticidal value was claimed. This sediment consists largely of sulphite of lime which has not been reliably shown to have any marked insecticidal properties.

ENTOMOLOGICAL DEPARTMENT

The tussock moth in orchards.— The tussock moth (*Hemerocampa leucostigma*) appeared in more than its usual numbers during the summer of 1908 in the rural districts of western New York. A noteworthy feature of the outbreak was the presence of the caterpillars in orchards in several communities, where they did considerable damage to young fruits. The ravages of the pests were especially noticeable in the vicinity of Lockport, Ransomville and Middleport. A bulletin prepared by the Station, No. 312, contains a very complete account of the life history and habits of the insect, with full instructions by which destructive outbreaks may be completely prevented.

Commercial lime-sulphur mixtures.— During recent years, commercial preparations of the lime-sulphur wash have been introduced into this State, and in several centers of fruit production they have been extensively used to combat certain injurious insects and plant diseases. Thorough spraying with these mixtures at effective strengths has generally given satisfactory results on the scale and the blister-mite. The commercial brands appear to be efficient substitutes for the home-made wash.

The attention of fruit growers is especially called to the variations in the densities of the clear solution, and in the amounts of sediment in the different brands. The range of density was from 26.8 to 33.9 degrees Beaumé, and the variation in sediment was from 0 to 19.42 per ct. Manufacturers of the leading brands are now establishing a standard strength for their solutions which they guarantee to the purchaser.

The strengths of effective mixtures for the scale, using a solution testing 33 degrees Beaumé, range from one gallon of the concentrate diluted with eight gallons of water to one gallon diluted with eleven gallons of water. In orchards in which the scale is not thoroughly controlled the stronger mixtures are recommended. A dilution of one gallon of the concentrate to eleven gallons of water makes an effective spray. Present evidence indi-

cates that the common spraying arsenicals may be safely combined with diluted lime-sulphur solutions.

Directions are given for making the home-made concentrated lime-sulphur wash. This method of preparing a sulphur spray has several advantages and should be tested by fruit growers to determine its applicability under their own conditions.

DEPARTMENT OF HORTICULTURE.

A comparison of tillage and sod mulch in an apple orchard.— In Bulletin 314 an attempt is made to answer the question as to whether the apple thrives better under tillage or in sod. The method of tillage chosen for the experiment was to plow in the spring, cultivate until late July, and follow with a cover crop. The sod method chosen was that known as the sod-mulch method in which the grass is cut as a mulch. The experiment was begun in 1903 in the orchard of W. D. Auchter, near Rochester, New York. This orchard consists of nine and one-half acres of Baldwin trees set in 1877, forty feet apart each way. The number of trees in the sod plat is 118; in the tilled plat, 121. In typography the Auchter orchard is rolling. The soil is a Dunkirk loam to a depth of ten inches, underlain by a sandy subsoil. The trees in the two plats received identical care in all orchard operations excepting soil treatment. The grass in the sod plat was cut twice in three of the five years, in the other two but once. The tilled land was plowed each spring and cultivated from four to seven times. Statements of results follow:

The average yield on the sod plat for the five years was 72.9 barrels per acre; for the tilled plat, 109.2 barrels; difference in favor of tilled plat, 36.3 barrels. Estimates made at blooming and fruiting time showed a far greater number of fruits on the tilled trees. Actual count showed 434 apples per barrel on the sod land weighing 5.01 ounces each and 309 apples per barrel on the tilled plat weighing 7.04 ounces each. The fruit from the sod-mulch plat matures from one to three weeks earlier than that on the tilled plat. In common storage fruit from the tilled plat

keeps four weeks longer than that from the sod plat. In cold storage, the keeping quality of the two fruits is the same. The tilled fruit is decidedly better in quality, being crisper, more juicy and of better flavor. The advantage of tillage over the sod-mulch in the matter of uniformity of trees and crops is marked. The trees in sod showed abnormalities in foliage, branches, roots and particularly in fruit-bearing and in fruit characters. The average gain in diameter of trunk for the trees in sod for the five years was 1.1 inches; for the trees under tillage 2.1 inches; gain in favor of tillage, 1 inch. The dark, rich green color of the foliage of the tilled trees indicated that the tilled trees were in the best of health. The leaves of the tilled trees were much larger and much more numerous. Leaves from sodded trees and the same number (2,400) from tilled trees were weighed and gave 8.7 grams as the average weight per leaf for the sodded trees and 11.5 grams for the tilled trees. The leaves of the tilled trees came out three or four days earlier and remained on the trees a week or ten days later than on the sodded trees. The average annual growth of branches for the sodded trees was 1.9 inches; for the tilled trees 4.4 inches. The average number of laterals per branch on the sodded trees was 3.4; on the tilled trees 6.7. The new wood on the tilled trees was plumper and brighter in color, indicating better health. The amount of dead wood in the sod-mulch trees was much greater than in the tilled trees. The roots of the trees in the sod-mulch plat came to the very surface of the ground. In the tilled land the roots were found in greatest abundance at a depth of from three to ten inches. The circumference of the root systems in the tilled trees is approximately circular, but the circumference of the roots of the trees in sod is very irregular, indicating a reaching out of a part of the roots in response to a demand for more moisture, food, or air. The average cost per acre for the two methods of management, not including harvesting, was $17.92 for the sod; and $24.47 for tillage, giving a difference of $6.55 in favor of the sod. The average net income per acre for the sod plat was $71.52; for the tilled plat $110.43, a differ-

ence of $38.91 in favor of tillage, an increase of 54 per ct. for tillage over the sod-mulch method of management.

Tillage seems to be better than sod for the apple for the following reasons: The results of 120 moisture determinations in the Auchter orchard show that the differences in tree growth and crop in the two plats of this experiment are mainly due to differences in moisture, the tilled plat having most moisture. As a consequence of the reduced water supply in the sod plat, there is a reduced food supply; for it is only through the medium of free water that plants can take in food. Analyses show that the differences between the actual amounts of plant food in the two plats are very small. Analyses show that there is more humus in the tilled plat than in the sod plat, contradicting the oft-made assertion that the tillage method of managing an orchard "burns out the humus." At a depth of six inches, the tilled soil is 1.1 degrees warmer in the morning and 1.7 degrees at night, than the sod land; at twelve inches the tilled soil is 2.3 degrees warmer in the morning and 1.8 degrees in the evening. We are justified, without the presentation of specific data, in saying that a tilled soil is better aërated than sodded land. Soil investigators are well agreed that beneficial micro-organisms are found in greater numbers in a cultivated soil than in other soils.

The following application of the results of this experiment may be made: Nearly all the plants which minister to the needs of men are improved by tillage; the apple does not seem to be an exception. Results as positive as in this experiment can be made very comprehensive; they should apply to all varieties of apples and to nearly all soils and locations. The experiment does not show that apples cannot be grown in sod; it suggests, however, that apples thrive in sod, not because of the sod but in spite of it. While moisture is by no means the only factor to be considered in the controversy over the sod and tillage methods of managements, it appears to be the chief one. There is nothing in this experiment to indicate that trees will become adapted to grass.

The grape districts of New York and table of varieties.— The basis of Bulletin 315 is "The Grapes of New York," prepared by this Station and published by the State Department of Agriculture. In collecting the material for the grape book, much valuable information was contributed by the grape-growers of New York in co-operation with the Station. The edition of the larger work was necessarily limited. It was the purpose of this bulletin to place before the grape-growers an accurate summary of the information contained in the grape book. The bulletin contains: First, a discussion of the natural factors influencing grape culture. Second, an account of the location, soil, climate, history and present status of the four great grape districts of New York. Third, a brief description of the most important species of Vitis, giving their natural habitat, botanical differences and horticultural importance, with the object of showing their significance in varieties. Fourth, a table of 161 of the most important varieties, giving the species, fruit and vine characters, date and place of origin or introduction, and a brief statement of their value for the grower.

INSPECTION WORK.

Fertilizers.— During the year 1909, 722 samples of fertilizers were received from the Commissioner for analysis, and results of their examination are given in Bulletin 318. The chemical staff of the Station has also furnished evidence in several suits that have been brought by the Commissioner of Agriculture for violation of the fertilizer law.

Feeding stuffs.— The number of samples of feeding stuffs analyzed at the request of the Commissioner of Agriculture during the past year has been 403. Bulletin 316 contains the results of these analyses. It is shown, as has been the case for several years, that many brands of feeding stuffs, especially those that are compounded from two or more ingredients, contain materials of very inferior quality, such as ground corn cobs, oat hulls, ground peanut shells, mill screenings and elevator sweepings. It is hoped that the amendment to the feeding stuff law, requiring

manufacturers to state the ingredients that enter into a mixed feed, will greatly aid consumers in avoiding feeds that are inferior in quality.

PUBLICATIONS ISSUED DURING 1909.

BULLETINS.

No. 311. January. Potato spraying experiments in 1908. F. C. Stewart, G. T. French and F. A. Sirrine. Pages 38.

No. 312. January. The tussock moth in orchards. W. J. Schoene. Pages 11, plates 3. Popular edition, pages 5.

No. 313. February. Inoculation and lime as factors in growing alfalfa. H. A. Harding and J. K. Wilson. Pages 25, plates 2, maps 2. Popular edition, pages 6.

No. 314. March. A comparison of tillage and sod mulch in an apple orchard. U. P. Hedrick. Pages 56, color plate 1, plates 7. Popular edition, pages 20.

No. 315. March. The grape districts of New York and table of varieties. M. J. Dorsey. Pages 29.

No. 316. August. Inspection of feeding stuffs. Pages 89.

No. 317. September. Milking machines; effect of method of handling on the germ content of the milk. H. A. Harding, J. K. Wilson and G. A. Smith. Pages 40, plates 4. Popular edition, pages 10.

No. 318. November. Report of analyses of samples of fertilizers collected by the Commissioner of Agriculture during 1909. Pages 90.

No. 319. December. Chemical examinations of lime-sulphur mixtures. L. L. Van Slyke, C. C. Hedges and A. W. Bosworth. Pages 36. Popular edition with No. 320, pages 14.

No. 320. December. Concentrated lime-sulphur washes. P. J. Parrott. Pages 30. Popular edition, with No. 319, pages 14.

No. 321. December. Director's report for 1909. W. H. Jordan. Pages 18.

TECHNICAL BULLETINS.

No. 9. February. A mycosphærella wilt of melons. J. G. Grossenbacher. Pages 25, plates 6.

No. 10. September. A volumetric method for the determination of casein in milk. L. L. Van Slyke and Alfred W. Bosworth. Pages 19, plate 1.

No. 11. November. Bacterial soft rots of certain vegetables. I. Studies of the causal organisms. H. A. Harding and W. J. Morse. II. Pectinase, the cytolitic enzym produced by *Bacillus carotovorus* and certain other soft rot organisms. L. R. Jones. Pages 120, figs. 10.

No. 12. December. Winter injury, collar rot and arsenical poisoning. J. G. Grossenbacher. Pages 40, plates 8.

CIRCULARS.

No. 10. March 10. Lime and liming. L. L. Van Slyke. Pages 12.

No. 11. November 10. Orchard management. U. P. Hedrick. Pages 12.

No. 12. December 21. Dwarf apples. U. P. Hedrick. Pages 8.

W. H. JORDAN,

Director.

New York Agricultural Experiment Station,
Geneva, N. Y., Dec. 31, 1909.

REPORT

OF THE

Department of Bacteriology.

H. A. Harding, *Bacteriologist.*
M. J. Prucha, *Associate Bacteriologist.*
James K. Wilson, *Assistant Bacteriologist.*

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REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

INOCULATION AND LIME AS FACTORS IN GROWING ALFALFA.*

H. A. HARDING AND J. K. WILSON.

SUMMARY.

1. The results from more than 100 cooperative experiments in growing alfalfa, located in over one-half of the counties of the State, indicate that where neither lime nor inoculation is applied the chance of a successful crop is not more than 20 per ct., or one chance in five.

2. Where lime is added to the land at the rate of 1,500 lbs. per acre the chance of success is raised to 40 per ct., or two out of five.

3. Where inoculating soil is applied alone, at the rate of 200 to 300 lbs. per acre, the chance of success is raised to about 60 per ct., or about three chances out of five.

4. Where both lime and inoculation are applied as above indicated the chance of a successful crop is raised to about four out of five.

5. Each farmer intending to try the growing of alfalfa should restrict his seeding to a single acre and so arrange that acre as to determine what line of treatment is required by his field.

*A reprint of Bulletin No. 313.

INTRODUCTION.

This publication summarizes the results of co-operative experiments which have been conducted in practically all parts of this State since 1905. The object of these experiments was to get a measure of the real need of inoculation and of lime in connection with the growing of alfalfa on the farms of this State, and, so far as possible, to determine the relative importance of these lines of treatment in connection with the growing of this crop.

Any study of this kind should be made upon a comparatively large amount of data in order to arrive at dependable results; and in securing this data quality should not be sacrificed for quantity. Moreover, if the results are to represent general relations it is necessary that the cases studied shall be so selected as to represent average conditions.

In this study, experiments have been conducted on about 200 farms scattered through the agricultural portions of this State. However, the necessity of basing the conclusions upon dependable experiments only has made it necessary to eliminate nearly one-half of these because of serious mistakes in laying out or conducting the experiments or of failures to report the required data. While this exclusion was solely for the reasons named it has acted in a somewhat selective manner since in those cases where the experiment early became a failure from natural causes there was a greater tendency to neglect to furnish the required data than in the cases where it seemed a success from the farmer's point of view.

As a result of this, the percentages of success in growing alfalfa are probably higher, in the results here given, than they would really be in practice. However, this error can not be very large, since the untreated check plats here recorded only show a successful crop in 20 per ct. of the cases. It is hard to believe that in the days before the need of inoculation and of lime was understood the failure in growing alfalfa in this State occurred oftener than four cases out of five.

ACKNOWLEDGMENTS.

In presenting this summary of experiments conducted in co-operation with approximately 200 farmers in this State it is a pleasure to acknowledge the assistance which these farmers have rendered in this connection. While we trust that, as with all work done for others, good has resulted to each of them, they have given freely of their time, thought and substance that their fellow farmers might know better how to meet their problems. As a result of this united effort there is now available a reasonably accurate measure of the importance of two of the main factors in growing alfalfa in this State and this evidence could be obtained in practically no other way.

The records of many of these experiments are given in their appropriate place but there are almost as many that are not so recorded because the circumstances of the experiment rendered the results of doubtful value. These accidents or mistakes were largely due to the inexperience of the farmers or of their help and are to be expected in such work. The spirit which led them to try to help their fellows is worthy of commendation and the experience gained will assist them in being of further service.

I. EFFECT OF INOCULATION.

PREVIOUS EXPERIMENTS.

Inoculation as a factor in growing alfalfa was discussed in Bulletin 300[1] on the basis of observations made upon 67 experimental fields distributed among about one-half of the counties of this State. These experiments were begun during the seasons of 1905 and 1906 and the observations extended over two growing seasons.

These observations indicate that the bacteria which form nodules on the roots of the alfalfa and enable this plant to make use of the free nitrogen of the air are present in small numbers in practically all alfalfa fields. However, it was in

[1] Harding, H. A. and Wilson, J. K. Inoculation as a factor in growing alfalfa. N. Y. Agr. Exp. Station Bul. 300. March, 1908.

only about one-third of these fields that they were present in sufficient numbers to produce an inoculation of any considerable number of the young alfalfa plants.

An attempt to supply the germs by applying pure cultures of *Ps. radicicola* to the seed, drying and sowing, resulted in an almost complete failure.

Applying soil from an old alfalfa field at the rate of 150 to 300 pounds per acre invariably produced an abundant inoculation on these experimental plats.

While but 15 of the 67 experimental plats produced a successful crop of alfalfa without inoculation, 48 adjacent plats where inoculating soil had been applied produced successful crops. Accordingly alfalfa growing on 33 of the 67 fields which were tested was changed from a failure to a success by the application of inoculating soil.

EXPERIMENTS BEGUN IN 1907.

During the season of 1907 soil from our alfalfa field was furnished for 49 experiments and the attempt was made to test on that number of fields the need of inoculation in connection with alfalfa growing and the results of supplying this inoculation by means of inoculating soil. Our experience of this season is a duplicate of that of the two preceding years in that mistakes were made in laying out the experiments in a number of fields and in other cases the necessary data could not be obtained after the experiments had been started.

The attempt has been made to exclude from our calculations all experiments in which the plats were so located or handled as to render the results questionable or where the data are incomplete. Accordingly the present publication gives the results from only 33 of the 49 experiments. While it is true that some of the 16 experiments which are not included were failures, others produced successful stands of alfalfa on some of the plats. They have all been rejected solely because the factors which produced the results could not be determined from the data at hand.

PLAN OF THE EXPERIMENTS.

All but one of the 33 experiments here reported were laid out in accord with the adjoining diagram. It will be noted that this plan provides for a test of the effect of inoculation and of lime separately and in combination and reserves one-quarter of the area untreated as a check, or basis for measuring the effect produced. According to this plan the lime was applied along the slope of the experimental acre some days before the sowing of the seed and well worked into the soil. The results obtained from the application of lime alone and in combination with inoculation will be presented under their appropriate headings.

No lime, no inoculation	Lime, no inoculation
No lime, inoculation	Lime and inoculation

Down-hill side of field

The inoculating soil was furnished from a field at this Station and was sown broadcast at the rate of 200 to 300 lbs. per acre just before sowing the seed. Thus the harrowing which covered the seed mixed it at the same time with the inoculating material. The half-acre which was inoculated lay across the slope of the hill in such a way that any washing which might occur would not carry the inoculation to the other half of the acre. Likewise in putting in the seed it was necessary to sow and harrow the uninoculated half of the field first to avoid spreading the inoculation by means of the machinery. Considerable care is required on the part of the one who lays out this experiment correctly but it is far cheaper than to lose a seeding because neither lime nor inoculation was used or to apply both to a large field when one or both were not needed. From an acre laid out in this way any farmer can see for himself just how his soil responds to these lines of treatment, and this form of experiment is strongly recommended to all who are beginning to grow alfalfa.

The two valid objections to the use of soil for inoculating purposes are the initial cost of the soil and the danger of introducing pests. Both of these objections are successfully met by the above plan of experimentation. The bag of soil required for a half-acre can usually be obtained from a neighbor or from the Experiment Station and if purchased in the market may be had for one dollar and the cost of transportation. After such an experiment, in case it is found that inoculation is necessary, the experimental plat will furnish enough soil to inoculate a number of farms, if desired. Again, the amount of land which is originally inoculated is small and if results show that dodder or any other pest has been introduced the problem of combatting it is not a serious one. While it is undoubtedly true that pests may be distributed by soil our correspondence and observations extending over a number of seasons have not brought to light a single instance where this has actually occurred.

SUMMARY OF INOCULATION EXPERIMENTS BEGUN IN 1907.

The results obtained from the 36 experiments which were properly conducted and reported are given in Table I:

TABLE I.—EXPERIMENTS, BEGUN IN 1907, SHOWING EFFECT OF INOCULATING SOIL ON ALFALFA CROP.

Name	Post office	County	Township	Check		Inoculated	
				Nodules	Success	Nodules	Success
Barber, M. J. . .	Silver Springs	Wyoming . . .	Gainesville .	+	—	+	+
Brigham, A. L.	Solsville.	Madison.	Eaton.	+	+	+	+
Brownlie, T. . . .	Peekskill. . . .	Westchester .	Cortland . . .	+	—	+	—
Child, S. H. . . .	Malone.	Franklin. . . .	Malone.	+	—	+	+
Clark, W. S . . .	Hornell.	Steuben.	Hornellsville	+	—	+	+
Crandall, S. G.*	Andover.	Allegany. . . .	Alfred.	+	+	+	+
Crandall, S. G. .	Andover.	Allegany. . . .	Andover. . . .	+	—	+	—
Crandall, S. G. .	Andover. . .	Allegany. . . .	Andover. . . .	+	—	+	—
Dimmick, E. H.	Halcottsville.	Delaware. . . .	Middletown	+	—	+	—
Emerson, Dr. H	Peconic.	Suffolk.	Southold. . .	+	—	+	—

TABLE I.—*Continued.*

Name	Post office	County	Township	Check		Inoculated	
				Nodules	Success	Nodules	Success
Eno, H. N.	Martville	Cayuga	Ira	+	—	+	—
Ferrin, F. J.	Springville	Erie	Concord	+	—	+	—
Gould, Jas. A.	Ensenore	Cayuga	Scipio	+	+	+	+
Hatch, L. C.	Lebanon	Madison	Lebanon	+	+	+	+
Kane, T. C.*	Scio	Allegany	Scio	+	—	+	—
Kelley, G. W.	Halcottsville	Delaware	Middletown	+	—	+	—
Lewis, A. S.	Ellenburgh	Clinton	Moores	+	—	+	—
Lyke, J. S.*	Ithaca	Tompkins	Ithaca	?	—	?	—
Lyon, Archie	Black Creek	Allegany	Hudson	+	—	+	—
McAuley, Jas.	Davenport	Delaware	Davenport	+	—	+	+
McCarthy, W.A.	Addison	Steuben	Tuscarora	+	+	+	+
Miller, F. A.	Earlville	Madison	Lebanon	+	+	+	+
Niles, W. F.	Salamanca	Cattaraugus	Little Valley	+	+	+	+
Nichols, T. B.*	Frankfort	Herkimer		+	—	+	—
O'Brien, A. F.	Mooers Forks	Clinton	Mooers	+	—	+	—
Rice, H. B.†	Ceres	Allegany	Genesee	+	—	+	—
Reed, H. V. D.	Amenia	Dutchess	Amenia	+	—	+	+
Sackett, B. H.*	Dundee	Yates		?	—	?	+
Sheppard, J. W.	Watkins	Schuyler	Dix	+	—	+	+
Sherwin, W. A.	Malone	Franklin	Malone	+	+	+	+
Stickle, Judson.	Fillmore	Allegany	Hume	+	—	+	—
Whitmore, C. S.	Addison	Steuben	Addison	+	—	+	+
Welch, T. J.	Granville	Washington	Granville	+	—	+	—
Whitney, C. H.	Greigsville	Livingston	Genesee	+	+	+	+
White, L. J. F.†	Ceres	Allegany	York	+	—	+	—
Wires, Carlton.	Winthrop	St. Lawrence	Stockholm	+	+	+	+
Totals				+34 ? 2	+10 —26	+34 ? 2	+18 —18

* This field was not seen by a Station representative.
† Sowed August 30 and 31.

The basis of computation in preparing this table was the same as that used in Bulletin 300. The presence of nodules on the roots was settled by direct examination; and the reports made by the farmers were checked by examinations made in practically all cases by a Station representative. The hay actually produced was the basis for deciding whether a plat was a suc-

cess or a failure. The deciding point was not so much the absolute amount of hay produced, as that would vary greatly with different land, but was rather the feeling of the owner as to whether the hay produced on any plat in the second season was sufficient to make a profitable return from the land. In all of these experiments except those of Messrs. Kane, Lyke, Nichols and Sackett and one of the experiments of Mr. Crandall, the fields were personally examined by a Station representative, usually just before time for cutting the hay.

It will be noted that some nodules were found on plants on all of the check plats, with the possible exception of the two experiments for which this information is lacking, even though no inoculating soil was applied to them. These experiments from which data are lacking were killed out during the winter and before observations on this point had been recorded. This constant presence of a small amount of inoculation scattered over the check plat is in accord with the previous experiences recorded in Bulletin 300. It seems to be fully demonstrated that a small amount of inoculation is present in practically all fields of alfalfa but the source of this inoculation is still in doubt. It may be introduced by the alfalfa seed but it seems to be more probable that it is derived from the adaptation of germs which have been previously associated with some of the other legumes. In a considerable number of the check plats the amount of the inoculation was very slight indeed, showing only as an occasional nodule on a few plants. When present in such small amounts it is of no practical importance except as it furnishes an explanation for the frequently successful results obtained where the growing of alfalfa was repeatedly tried upon the same field without intentional inoculation and finally became a success.

Inoculation was, of course, present in all of the plats to which inoculating soil had been applied at the rate of 200 to 300 lbs. per acre; but what was really important, with the exception of the experiment of Dr. Emerson, this inoculation seemed to be present in an amount sufficient for the needs of the plant. The

experiment with Dr. Emerson is conspicuous as the single case in all of our experiments in which the soil from the Station alfalfa field apparently failed to produce any marked effect upon the inoculation of the plats. In this case the soil was held three months in storage in a dry place before being used and the germ content of the same probably suffered from excessive drying. We have learned of two similar failures where a bag of soil was held from one season to the next before being applied.

The influence of the inoculating soil is brought out sharply when we consider the relative success of the plats which received the inoculating soil as compared with those which did not. Of the 36 check plats 10 produced enough hay to be considered a success while among an equal number of adjoining plats to which inoculating soil had been applied 18 were successful. This is a somewhat higher proportion of success among the check plats as well as a smaller proportion of success among the inoculated plats than during the two preceding seasons. Where the numbers are so small considerable variations in the results are to be expected.

It should not be inferred from these results that the effect of the inoculating soil is limited to the fields which were changed from a failure to a success. On the contrary, it produced a noticeable improvement in practically all fields except those where the proper bacteria were already present in sufficient numbers to meet the requirements of the plants. In some of the experiments which were recorded as a success without artificial inoculation the adjoining inoculated plats produced even more successful crops showing that the natural inoculation was not up to the full requirements of the alfalfa. However, this latter difference probably would become less noticeable as time passed.

SUMMARY OF EXPERIMENTS BEGUN IN 1905–07.

The true situation in this State with regard to the need of inoculation in connection with the growing of alfalfa is best

seen by bringing together the results of the observations on the experiments begun in 1905–06–07.

TABLE II.—SUMMARY OF THE EFFECT OF INOCULATION ON ALFALFA.

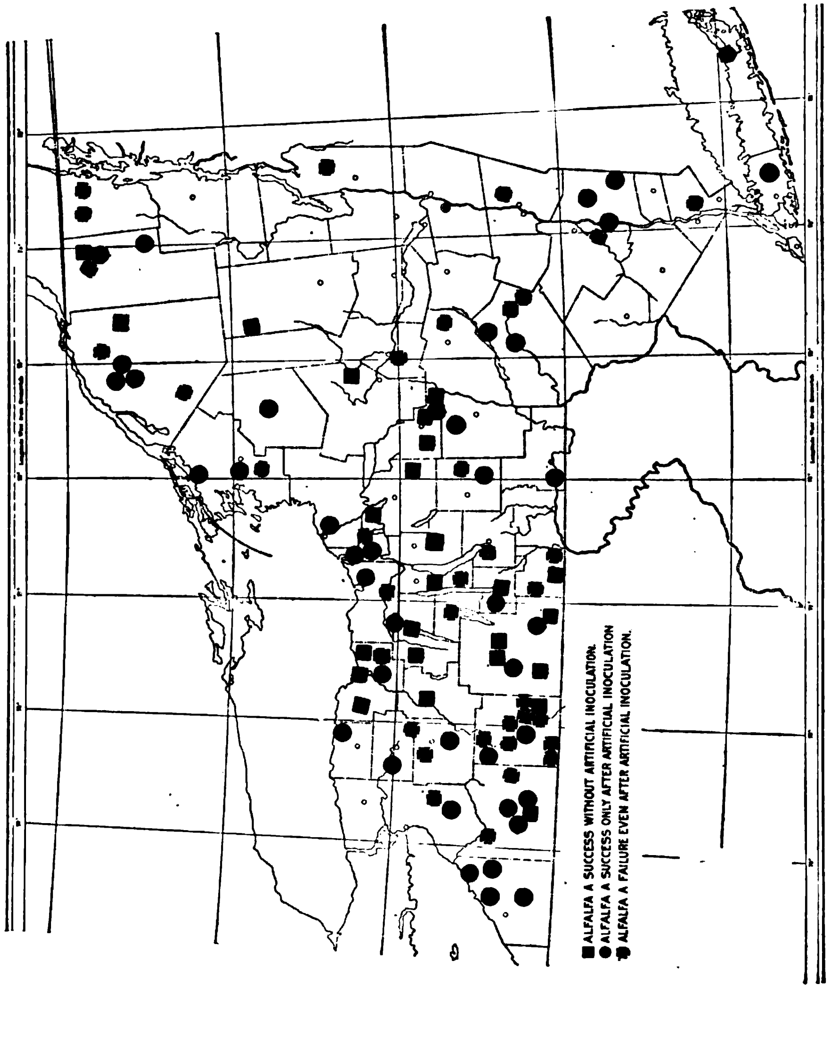
Year	No inoculation, success		Inoculation, success	
	+	—	+	—
1905	10	24	24	10
1906	5	28	24	9
1907	10	26	18	18
Totals	25	78	66	37

This shows that among 103 experimental fields there were but 25 where a successful crop of alfalfa was produced without the aid of inoculating soil. This would indicate that under such circumstances the chance of a success is only about one in five.

Again it is seen that 66 of the adjoining plats to which inoculating soil had been applied produced successful crops of alfalfa. Here the use of this soil from our alfalfa field has increased the number of successful fields by 40 per ct. and this would indicate that where inoculating soil is used in connection with the sowing of alfalfa the chance of getting a successful crop is about three out of five. From these experiments it would seem plain that in beginning to grow alfalfa proper inoculation of the soil is a point which is worthy of the careful attention of any farmer in this State.

GEOGRAPHICAL DISTRIBUTION OF INOCULATION EXPERIMENTS.

The 36 experiments here recorded represent 20 counties and, taken in connection with the 67 experiments recorded in Bulletin 300, give returns from one or more fields in 39 of the 61



MAP 1.—LOCATION AND RESULTS OF ALFALFA INOCULATION EXPERIMENTS.

counties of the State. The wide distribution of these experiments as well as the character of the results obtained from them is shown by Map I. From this it will be seen that they cover the State fairly except in the mountainous regions.

II. EFFECT OF LIME.

It is a frequent observation among farmers that an application of ashes to soil results in a more vigorous growth of members of the clover family. This result is due partly to the potash and phosphates which are contained in the ashes; but practically the same result follows the application of the residue after the soluble salts have been removed from the ashes in the process of home soap making. Unleached wood ashes carry about 600 lbs. of lime to the ton and much of this favorable action of ashes upon the growth of legumes is ascribed to the action of the lime.

In recent years the effect of lime applied in a variety of forms has been extensively studied with regard to its effects both on the soil and on the plants. Our interest in this connection is limited to consideration of its value in connection with the starting of alfalfa. Those interested in its broader aspects are referred to the publications on this subject by the various agricultural experimental stations, particularly that of Rhode Island.

Practically every recent publication on alfalfa growing has laid stress upon the necessity of applying lime, in many cases, before success can be expected with this crop; but the data upon which these statements are based is not given. An exception to this is Pennsylvania Station Bulletin 79[2] which states that "Lime has not given satisfactory results. In some instances it has given no appreciable results; in others it has been decidedly harmful; in no case was it applied to advantage." The authors of Cornell Bulletin 237[3] find that the situation is dif-

[2] Watson, Geo. C. Alfalfa as a forage crop in Pennsylvania. Penn. Agr. Exp. Station Bul. 79, September, 1906.

[3] Hunt, Thos. F, Stone, J. L, Gilmore, John W. and Fraser, Samuel. Alfalfa. N. Y. Cornell Station Bul. 237, March, 1906.

No treatment. Inoculation, no lime. Lime, no inoculation. Inoculation and lime.

PLATE I.— HAY FROM EQUAL AREAS ON ALFALFA PLATS WITH DIFFERENT TREATMENT.

ferent in this State and give the following data: "Seventeen reports [of co-operative experiments] state that lime was applied to part of the area sown to alfalfa, and part left without lime for comparison. Of this number ten state that the limed area was decidedly better than the unlimed. Six state that there was no benefit and one reports apparent damage. The marked effect of lime in the experiments conducted on some heavy soil of the college farm, * * * taken in conjunction with these results secured throughout the State, indicate that liming takes an important place in connection with alfalfa growing in New York."

METHODS OF APPLYING THE LIME.

Practically all forms of lime are used in connection with alfalfa and they seem to be valuable in proportion to the amount of available calcium which they contain. In practically all of these experiments stone lime was used because it could always be obtained and was of fairly constant composition. Likewise 1500 lbs. per acre was the amount arbitrarily selected for application as this was midway between the extreme amounts which are being used in practice.

Lime is sparingly soluble and in order to get prompt returns from its application it seems necessary to apply it in a finely divided condition and to mix it intimately with the soil. The difficulty in application comes largely from its irritating action on the skin and eyes. On this account, the early morning of a quiet day is preferable for the work.

Where only a small area is to be treated, as in our experiments, it is usually preferable to place the stone lime in small piles, throw on a little moist earth or add a little water to hasten slaking and, when the lime is reduced to powder, spread with a shovel.

Where large lots are to be applied the lime can be readily slaked by sprinkling with water as it is shoveled over and can be applied with any machine for applying fertilizers or with a shovel from a wagon. The difficulty with the former is that the

ordinary machinery will not deliver as much per acre as is needed and the land must be gone over at least twice; while in applying it from a wagon there is a marked tendency for the dust to be extremely irritating unless the wind is just right.

EXPERIMENTS BEGUN IN 1905.

In the experiments which were begun in this year for the purpose of testing the effect of inoculation the farmers were left largely to their own resources in the matter of testing other factors.

Lime was suggested as one of the factors which it was especially desirable to observe. Among the experimenters who used lime in some form in their alfalfa fields five of them so arranged their plats as to give dependable results, which are shown in Table III.

TABLE III.—EXPERIMENTS BEGUN IN 1905 SHOWING THE EFFECT OF LIME ON ALFALFA.

Name	Post Office	County	Township	No lime	Lime	
				Success	Improvem't	Success
Carr, Geo. L.	Martville	Cayuga	Sterling	—	+	+
Clothier, H. B.	Silver Creek	Chautauqua	Hanover	—	+	—
Potter, Jas. W.	Collins	Erie	Collins	—	+	—
Tobey, E. P.	Smyrna	Chenango	Smyrna	—	+	+
Wilcox, Chet.	Wellsburg	Chemung	Ashland	—	+	—
Totals				—5	+5	—3 +2

In all cases there was a noticeable improvement resulting from the use of lime and in two cases this improvement was sufficient to change a field from a failure to a success.

EXPERIMENTS BEGUN IN 1906.

The uniform improvement observed from the application of lime in the experiments begun in 1905 led us to urge the farmers who were beginning the culture of alfalfa in 1906 to test the effect of lime. Among the experiments started this season 22 were so conducted as to give dependable results and these results are given in Table IV.

TABLE IV.—EXPERIMENTS BEGUN IN 1906 SHOWING EFFECT OF LIME ON ALFALFA.

Name	Postoffice	County	Township	No lime	Lime	
				Success	Improvem't	Success
Bennett, B.*	Hornell	Steuben	Haward	—	+	+
Bennett, F.*	Hornell	Steuben	Haward	—	+	+
Brown, W. H.	Vestal Center	Broome	Vestal	—	+	—
Bullis, Jas.	Canton	St Lawrence	Canton	—	+	+
Burns, G. C.	Burdette	Schuyler	Hector	+	+	+
Carman, A. A.	Barneveld	Oneida	Trenton	—	+	—
Dow, Chas. M.	Jamestown	Chautauqua	Randolph	—	+	—
Goodall, Dr. H.L.	Lake Kushaqua	Franklin	Franklin	—	+	—
Hammond, D.	Denver	Delaware	Roxbury	—	+	—
Hiller, H. R.	Alexander	Genesee	Alexander	—	+	—
Hinds, O. E.	Watertown	Jefferson	Pamelia	—	+	—
Irwin, W. A.*	Lafargeville	Jefferson	Orleans	—	+	—
Kingsbury, C. H.	Barnard	Monroe	Greece	—	+	+
Leach, J. A.	Marathon	Cortland	Marathon	—	+	—
Mosher, W. J.	Martville	Cayuga	Sterling	—	+	+
Northrup, Jay	Springville	Erie	Concord	—	+	+
Orr, W. J.	Attica	Wyoming	Bennington	—	+	—
Pitt, M. E.	Canton	St Lawrence	Canton	—	+	—
Reeves, D. F.	Steamburg	Cattaraugus	Cold Spring	—	+	—
Scott, J. F.	Elmira	Chemung	Elmira	—	+	—
White, Geo.	Elmira	Chemung	Elmira	—	+	—
Williams, K. R.	Earlville	Madison	Lebanon	—	+	—
Totals				+1 —21	+22 — 0	+ 7 —15

* Fields not seen by a Station representative.

It happened that among these experiments there was but one where the unlimed plat made a successful growth. In each of the 22 experiments the use of lime resulted in a distinct gain to the alfalfa and in 6 experiments this improvement was so marked as to produce a successful crop when the adjoining unlimed plat was a failure.

The lime applied in these experiments varied from 1000 to 2C00 lbs. per acre.

EXPERIMENTS BEGUN IN 1907.

In this year the experimenters were generally induced to lay out exactly an acre according to the plan given on page 35 and the Station paid for 750 lbs. of stone lime to be applied to one-half acre. Of the experiments of this year 37 were so conducted that the results seemed reliable and they are given in Table V.

TABLE V.—EXPERIMENTS BEGUN IN 1907 SHOWING EFFECT OF LIME ON ALFALFA.

Name	Postoffice	County	Township	No lime	Lime	
				Success	Improvem't	Success
Barber, M. J....	Silver Springs	Wyoming	Gainesville ..	—	+	+
Brigham, A. L...	Solsville......	Madison......	Eaton.......	+	+	+
Brownlie, Thos..	Peekskill.....	Westchester ..	Cortland	—	—	—
Child, S. H......	Malone.......	Franklin.....	Bangor......	—	+	+
Clark, W. S.....	Hornell	Steuben......	Hornellsville.	—	+	—
*Crandall, S. G..	Andover	Allegany.....	Alfred	+	+	+
*Crandall, S. G.	"	"	Andover	—	+	—
*Crandall, S. G..	"	"	Andover	—	+	—
Dimmick, E. H..	Halcottsville..	Delaware.....	Middletown..	—	+	—
Emerson, Dr. H.	Southold.....	Suffolk.......	Southold....	—	—	—
Eno, H. N......	Martville.....	Cayuga	Ira.........	—	+	—
Ferrin, F. J.....	Springville....	Erie.........	Concord.....	—	+	—
Gould, Jas. A....	Ensenore.....	Cayuga	Scipio.......	+	—	+
Hatch, L. C.....	Lebanon	Madison......	Lebanon	+	+	+

TABLE V.—*Continued.*

Name	Postoffice	County	Township	No lime	Lime	
				Success	Improvem't	Success
Kane, T. C.	Scio	Allegany	Scio	—	?	—
Kelley, G. W.	Halcottsville	Delaware	Middletown	+	+	+
Lewis, A. S.	Ellenburgh	Clinton	Mooers	—	+	—
Lyke, Jas. S.	Ithaca	Tompkins	Ithaca	—	+	—
Lyon, Archie	Black Creek	Allegany	Hudson	—	+	—
McAuley, Jas.	Davenport	Delaware	Davenport	—	+	+
McCarthy, W. A.	Addison	Steuben	Tuscarora	+	+	+
Miller, F. A.	Earlville	Madison	Lebanon	+	—	+
Niles, W. F.	Salamanca	Cattaraugus	Little Valley	+	+	+
Nichols, T. B.*	Frankfort	Herkimer	....	—	+	—
O'Brien, A. F.	Mooers Forks	Clinton	Moores	—	+	—
Reed, H. V. D.	Amenia	Dutchess	Amenia	—	+	+
Rice, H. B.†	Ceres	Allegany	Genesee	—	?	—
Sackett, B. H.*	Dundee	Yates	....	—	+	—
Sheppard, J. W.	Watkins	Schuyler	Dix	—	+	+
Sherwin, W. A.	Malone	Franklin	Malone	—	+	+
Stickle, Judson	Fillmore	Allegany	Hume	—	+	—
Thompson, F. E.	Seneca Falls	Seneca	Seneca	—	+	+
Whitmore, C. S.	Addison	Steuben	Addison	—	+	+
Welch, T. J.	Granville	Washington	Granville	—	+	—
White, L. C.†	Ceres	Allegany	Genesee	—	?	—
Whitney, C. H.	Greigsville	Livingston	York	+	—	+
Wires, Carlton	Winthrop	St Lawrence	Stockholm	+	—	+
Totals	....	....	....	+10 —27	+27 — 6 ? 4	+18 —19

* Fields not seen by Station representative.
† Fields sowed Aug 30 and 31.

It will be observed that 10 of the 37 experiments yielded profitable crops of hay without the addition of lime and that 18 adjoining plats where lime was applied were profitable. Lime produced an improvement in growth in all but six of the plats where data could be obtained upon this point. In four experiments, in which both plats were failures, data are lacking as to the effect of the lime.

SUMMARY OF THE OBSERVATIONS ON THE EFFECT OF LIME.

It should be remembered that in all of our experiments with alfalfa we have continued our observations over two seasons. The first winter is so severe a trial of the suitability of the conditions for the growth of alfalfa that observations made the second season are especially valuable.

In the larger proportion of the experiments the lime was applied at the rate of 1500 lbs. per acre. This application was usually in the form of stone lime which was distributed over the plat in small piles and allowed to slake, after which it was spread with a shovel and thoroughly worked into the soil some days before sowing the seed.

A summary of the observations made on experiments begun in the seasons of 1905–06–07 is given in Table VI.

TABLE VI.—SUMMARY ON EFFECT OF LIME ON ALFALFA

Year	No lime		Lime			
	Success		Improvement		Success	
	+	—	+	—	+	—
1905	0	5	5	0	2	3
1906	1	21	22	0	7	15
1907	10	27	27	6*	18	19
Totals	11	53	54	6	27	37

* Data lacking for four experiments.

From this table it is seen that the use of lime resulted in an improvement in 54 of the 64 fields where it was tried. In some fields the improvement produced was so slight that it was barely observable but in a large number of cases it made the difference between failure and success. It will be observed that there were but 11 successful plats among those which had not been

limed. On the other hand 27 of the adjoining plats to which lime had been applied produced successful crops. In these 64 experiments the application of lime alone increased the number of successful fields by 25 per ct. and all of the fields which were a success without lime were improved by its application.

In no case did these observations show any detrimental effects from the lime which was used. However, it should be remembered that in this work the amount of lime, usually 1500 lbs. to the acre, was a moderate application. It is entirely possible that a heavier application would have had a harmful effect in some fields.

While these experiments are too few and scattering to give an absolute measure of the conditions in any particular part of the State, so far as they go they show that the use of moderate amounts of lime brings improvement to the alfalfa crop in practically all cases. The relation of lime to the needs of his soil should be carefully tested by every farmer who is striving to grow alfalfa.

The problem as to what is the most profitable amount of lime to apply in each particular field has not been studied in these experiments. Such a study would have required an accurate weighing of the product from each plat and means for doing this were lacking at a large proportion of the farms at which we conducted our experiments. It seems evident from our observations that the amount of lime which should be applied to obtain the maximum profitable returns differs as widely in different fields as do their fertilizer requirements. The principle having been established, as the result of careful experiments, that liming is generally profitable with alfalfa in this State the farmer must work out for himself the details as they apply to his own land, just as he does the matter of the application of fertilizers.

LITMUS AS A TEST OF THE NEED OF LIME.

A ready means of determining the need of lime in connection with the growing of alfalfa would be a distinct advantage; and from the beginning of these experiments with alfalfa each

experimenter has been furnished with sensitive litmus paper for testing his soil. He was directed to apply this to different parts of the experimental area and return the used pieces of litmus paper to us so that the kind and depth of color produced by contact with the soil might be compared. These observations were supplemented in many cases by like tests of the fields made by a Station representative. In all but two of approximately 200 fields which have been thus examined the litmus has been turned a faint pink, indicating that there was present in the soil solutions an acid reaction. One of these exceptions was a small area in an otherwise acid-reacting field and this difference was ascribed by the owner to the fact that just at that point he had previously distributed a considerable amount of wood ashes. No explanation was found for the unusual reaction in the other field, in which this reaction was the same throughout. In this particular field which did not color the litmus pink the application of 1500 lbs. of lime to the acre made a marked improvement in the quality of the alfalfa. Where this application was combined with inoculation it produced a successful crop although the check was a complete failure.

The three fields where no improvement resulted from the application of lime are of special interest in this connection. All of these fields gave an acid reaction which did not seem to be different from that observed in the other cases. Of course it is possible that a heavier application of lime might have given good results in these cases.

More interesting evidence in this connection was accumulated by testing, with litmus paper, the reaction of the plats to which lime had been applied, especially in those cases in which its application resulted in a markedly improved growth of the alfalfa. The reaction of the soil in such cases, after the addition of the lime and the lapse of sufficient time, some weeks or months, to allow for a contact of the lime with the soil solutions, was not appreciably different, as judged by its action on litmus paper, from what it was on the adjoining check plats to which no lime had been applied.

While these results are too few to settle definitely the value of litmus paper as an indicator of the need of lime in growing alfalfa they indicate that little information of value can be obtained by an observation of its action.

III. THE COMBINED INFLUENCE OF LIME AND INOCULATION.

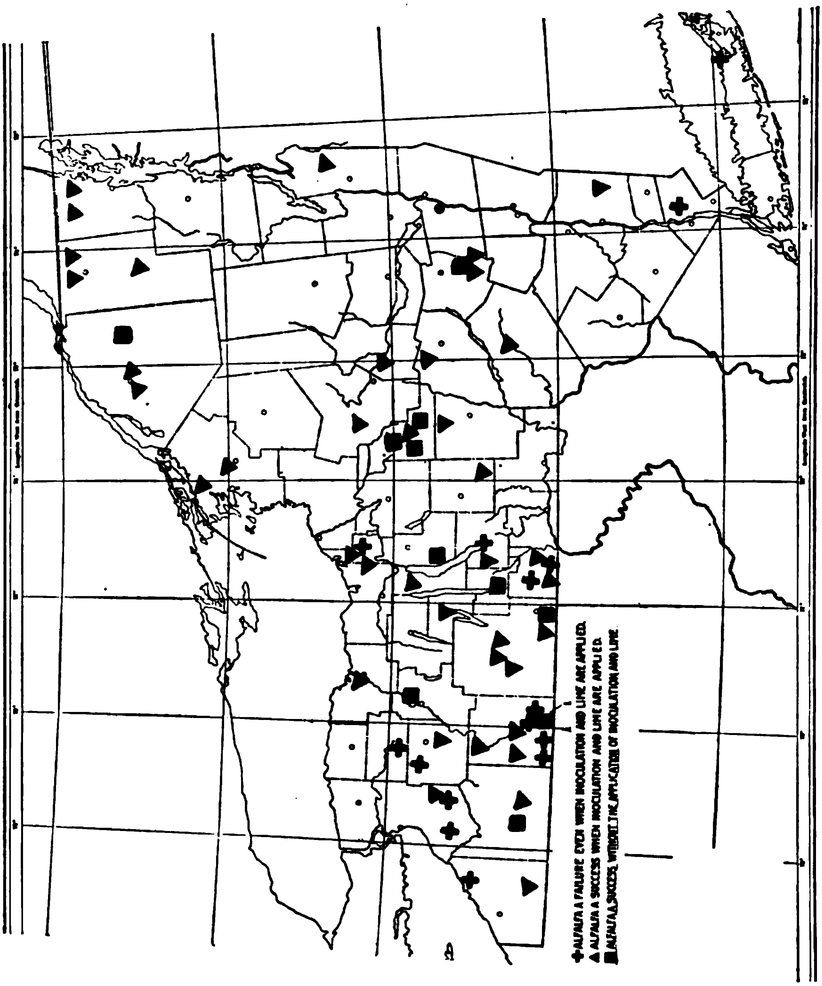
The results already given for inoculation indicate that in our experimental fields the addition of inoculating soil alone increased the chance of a successful crop about 40 per ct. and similar tests with lime alone indicate that by its use the chance of success was increased 25 per ct. Where both lime and inoculation were applied together it would be natural to expect that there would be a cumulative effect and that the chance of success would be increased by practically the sum of the two factors.

As has already been noted this combined effect has ordinarily been tested in connection with the same experimental plats upon which the factors were determined separately. This is especially true of the experiments begun in 1907 which were laid out according to the plan given on page 35.

A summary of the results observed in this connection in the experiments begun during 1905–06–07 is given in Table VII.

TABLE VII.—SUMMARY OF THE EFFECT OF INOCULATION AND LIME ON ALFALFA.

Year	No lime and no inoculation		Lime and inoculation	
	Success		Success	
	+	—	+	—
1905	0	5	2	3
1906	1	22	20	3
1907	11	26	28	9
Totals	12	53	50	15



MAP 2.—LOCATION AND RESULTS OF INOCULATION AND LIMING EXPERIMENTS WITH ALFALFA

From this table it is seen that reliable data on the combined action of inoculation and lime has been secured from 65 experiments. In these 65 experiments only 12 of the untreated check plats produced a successful crop of alfalfa while on the adjoining plats to which inoculation and lime had been applied 50 of the plats were a success.

Reduced to percentages this indicates that the application of the inoculation and lime has increased the chance of success from 18 per ct. on the check plats to 77 per ct. on the treated plats or an increase of 59 per ct. due to the treatment.

The distribution of these experiments and the indicated need of inoculation and lime are shown on Map 2.

The effect of the application of inoculation and of lime as well as the fact that there is a wide difference in the plats which are included in our summaries as a success is brought out in Plate I. This is from a photograph of the hay cut within a 36 inch circle on each of the four plats in the experiment of Mr. M. J. Barber, Silver Springs, Wyoming County, N. Y. The hay was cut June 12, 1908, almost exactly one year after the seeding of the plants. In Table I, page 36, in discussing the effect of inoculation the check plat is given as a failure and the inoculated plat as a success. In Table V, page 46, the lime plat is given as a success while the check is again referred to as a failure. Finally in the summary of the combined effect of inoculation and of lime, this experiment is included among those in which the combined application of inoculation and of lime changed a failure to a success. These three plats on which the yield is so markedly different are all rated as successes because in all cases the plats produced a yield which made a fair return from the land.

Plate II shows the effect of inoculation and liming upon the relative development of weeds and hay. These samples were cut on similar 36-inch circles on the plats in the experiment of James McCauley, Davenport, Delaware County.

CONCLUSIONS.

In considering the practical bearing of these results the fact must be constantly borne in mind that while the land upon which these experiments was conducted has been selected by the farmers, they have been urged to select land which was well drained and of a fair degree of fertility and to exercise great care in freeing the land from weeds before sowing the alfalfa. They were also urged to send samples of their seed to the Station for examination for dodder, trefoil and injurious weeds.

In view of the uniform character of the results of our experiments there can be no doubt but that, when the above conditions are observed, the natural lack of inoculation and of lime in the fields of this State is responsible for the larger part of the difficulty which has been experienced in the establishment of alfalfa.

Of these two the lack of lime is the more common, since practically all fields respond to its application. However, the lack of inoculation is more often the controlling factor and the application of soil changed about twice as many fields from a failure to a success as did the application of lime.

It should be kept in mind that when sufficient inoculation is already present in a field the addition of more is without any apparent effect upon the crop. When sufficient inoculation is not present the application of 150 to 300 lbs. of soil from an alfalfa field in which the plants are well provided with nodules will supply the necessary bacteria.

The application of inoculation or of lime will insure a crop of alfalfa only in so far as those are the only things which are lacking in that particular field. Good results can not be expected unless the land is well drained, of a reasonable degree of fertility and is so prepared for the crop as to destroy the maximum number of weed seeds and properly fit the land for the seed. When, in addition to these things, the seed is good and free from dodder and objectionable weed seeds, the farmer is ready to test the need of inoculation and of lime on the

particular field where he later hopes to produce alfalfa in large quantities.

The quickest and most economical method of finding the need of his soil with regard to inoculation and lime is to restrict his sowing to a single acre and lay out his acre according to the outline given on page 35.

When the farmer has determined the things needed by his soil in order to grow alfalfa successfully he can sow a considerable acreage and be reasonably sure of getting a successful crop.

MILKING MACHINES:*

EFFECT OF METHOD OF HANDLING ON THE GERM CONTENT OF MILK.

H. A. HARDING, J. K. WILSON AND G. A. SMITH.[1]

SUMMARY.

1. In this study the machines were operated in the Station stable and the general management of this was intentionally made to correspond closely to that of the better dairies supplying the city milk trade. No attempt was made here to copy the conditions surrounding the production of "certified" milk, but it is the intention to study these conditions later.

2. The Globe milking machine, as tested in our stable, was highly unsatisfactory. It did not remove all of the milk which the cows were prepared to give and it highly contaminated the milk as drawn.

3. The Burrell-Lawrence-Kennedy machines which have been tested were more successful. They appeared to remove practically all of the milk which the cows would give. An accurate comparison of the yield by machine and by hand milking is now in progress. The effects of the long continued use of the machine upon the cows and their value as time-saving elements are also being observed but as yet we are not able to give any definite conclusions.

[1] The study of milking machines is done through the co-operation of the Dairy and Bacteriological departments and in the investigation one of us (H) assisted in the planning of the work and in putting the results into literary form, another (W) was responsible for the bacteriological samples and the analytical work in connection with them while the other (S) had charge of the dairy and of the operation of the milking machines.

*A reprint of Bulletin No. 317.

4. The immersion of the teat cups and the rubber parts of the milking machine in a 10 per ct. solution of salt (NaCl) between milkings is important. This treatment reduced the average germ content of the milk from over 180,000 germs per cc. to less than 20,000 per cc.

5. The air filters were also important in proportion as they removed the germ-laden dust from the air which enters the pail during the milking process. On the later types of Burrell-Lawrence-Kennedy machines these filters were large enough to be quite efficient and the germ content of the milk, when the tubes had been held in brine and the filter cups had been properly filled with cotton, was almost always markedly below 10,000 per cc.

6. Dropping the teat cups on the floor during the milking process or any gross carelessness in handling the machine caused a surprising rise in the germ content of the milk. Occasionally very high counts were obtained when no definite cause could be found. Additional study is necessary before all of the important factors which influence the germ content of machine-drawn milk are understood.

7. These results do not demonstrate that the milking machine is a success because they cover only one of a number of important points in connection with the use of such machines. They do indicate that when machines of the better type are run properly they will deliver milk with a very low germ content.

8. At present the greatest difficulty in connection with the milking machine is to obtain the kind of man who will so operate the present machine as to obtain its maximum of efficiency and cleanliness.

INTRODUCTION

One of the most important factors retarding the proper development of dairying is the difficulty of getting milkers who can be depended upon to do their work satisfactorily. The size of the dairy, except in rare instances, is restricted to the number of cows which the owner can attend to at such times as his help fails him. The last census shows that in the State of New York, on farms where 40 per ct. or more of the income is derived from the sale of dairy products, there is an average of less than 14 cows per farm. Moreover, nearly one-third of the cows in this State are on farms not included in the above class and on these farms the average is less than 5 cows per farm.

If the question of milking the cows without being so dependent upon hired help could be satisfactorily solved, the number of cows kept on dairy farms would increase up to the limit of the ability of the acreage to feed the animals economically. Instead of an average of 14 per farm the average would be more than double that number. Dairying would then become a business on such farms, to be carefully studied and run on business lines, instead of being a minor matter to be little studied and less understood, as is now too often the case.

Because of the immense economic importance of this question of milking a keen interest has arisen in the milking machines which have been put upon the market during recent years. Inquiries concerning them have been constantly coming to this Station and satisfactory answers to these questions could not be given until these machines had been studied. Early in 1906 a Globe milking machine was installed in the Station barn. Owing to the withdrawal of this machine from the market in the winter of 1906 the Globe machine was replaced in the spring of 1907 by a Burrell-Lawrence-Kennedy cow milker which is being studied at the present time. During the past two years this latter machine has been undergoing rapid improvement and many statements which were made regarding the earlier types of this machine are not true of the machine which is now upon the market.

The first and most natural question, as to whether the milking machine will actually milk cows, is readily answered in the affirmative. Other questions relate to the effect of the continuous use of the machine on the cow, to its effect upon the quality of the milk produced and to its economy. The correct answers to these latter questions are not so easily obtained.

The question of the effect of the milking machine on the cow is an especially complicated one and although it has been studied already for more than three years, satisfactory data for its solution are not yet at hand. So far as the observations have gone it seems that when the vacuum with which the machine is operated is not excessive and the teat cups are so selected as to fit the teats properly the yield is probably as large as would be obtained by the ordinary hand milking. However, there is at present no basis, aside from experience, for determining what is the correct amount of vacuum. Again, in fitting the teat cups constant care is essential, as the size of the cup required by a given teat may vary at different periods of lactation. Recent mechanical changes in the machine appear to have further increased its ability to milk cows successfully. The study of the question of the effect of the milking machine upon milk secretion is being continued and it is hoped that a more accurate measure of its effect may be later obtained. Whether one man can milk more cows with one or two machines than he can by hand is also being observed.

The effect of the machine on the quality of the milk can be measured by the germ content of the milk and, as might naturally be expected, the effect depends largely upon the way in which the machine is manipulated. This publication deals with the influence which variations in the construction of the machine and in the manner of its manipulation have upon the germ content of the milk. It is hoped that a knowledge of these relations may guide the users of milking machines in producing a more desirable quality of milk and in producing it at a lower cost.

It should be clearly understood that in these studies of the action of milking machines the effort was made to run the machines in accordance with the directions of the manufacturers except in so far as it was necessary to vary the conditions in testing specific factors. The barn conditions were made to approximate as closely as possible those of a good farm dairy. There seems to be no reason why any dairy which is prepared to carry out the directions of the manufacturers may not confidently expect to reproduce the results here given provided the same care is exercised. As will be shown in detail, the quality of the milk produced by the milking machine depends almost entirely upon the exercise of intelligent care in operating it.

The surprisingly low germ contents recorded in connection with these studies under ordinary barn conditions indicate that when its operation is fully understood the milking machine may become an important factor in the production of "certified" milk, where great stress is laid upon producing a milk with a low germ content. It is the intention later to bring our barn to a condition comparable to that under which certified milk is being produced and observe the effect of this change on the product of the milking machine.

PREVIOUS STUDIES OF MILKING MACHINES

The earliest available study of the effect of a milking machine upon the germ content of the milk is that by Harrison.[1] In a dairy in which part of the cows were milked by hand and the others by the Thistle milking machine he repeatedly determined the germ content of the milk obtained in each way. An average of 24 such examinations of the product of the milking machine gave 150,000 germs per cc. while 17 tests of the milk drawn by hand gave 11,000 germs per cc. Likewise the keeping quality of the machine-drawn product was markedly inferior to that of the milk drawn by hand. In this machine there were no air filters and the rubber parts were scrubbed daily and kept in cold water between milkings.

Erf[2] traced the history of the development of the milking machines and discussed the action of the Burrell-Lawrence-Kennedy machine which he had under observation for some months.

Stocking,[3] in 1905, studied the Burrell-Lawrence-Kennedy machine as it was being used in two dairies. In both cases he contrasted the resulting germ content in the milk with that obtained when milk was drawn by hand. The unsatisfactory character of hand milking as a basis for comparison in such studies is shown by the fact that in one dairy the average results obtained by hand milking in different experiments varied from 48,125 to 786,382 per cc. and the other dairy from 997 to 11,712 per cc.

The most important point brought out in this study was the favorable effect on the resulting germ content of the milk when the rubber parts were kept between milkings in a solution of

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[1]Harrison, F. C. Machine-drawn milk versus hand-drawn milk. *Cent. f. Bakt.* II Abt. 5: 183–189. 1899.

[2]Erf, O. Milking machines. Kan. Agr. Exp. Sta. Bul. 140. Oct. 1906.

[3]Stocking, W. A., Jr. The milking machine as a factor in dairying. II Bacteriological studies of a milking machine. U. S. Dept. of Agr. B. A. I. Bul. 92. Jan. 1907.

common salt (NaCl). This improvement in the manner of keeping the rubber parts was the first step toward the production of milk of an acceptable quality and marks the beginning of the real solution of the problem of a sanitary milking machine.

The suggestion of this idea was due to some earlier observations of Mr. D. H. Burrell[4] on the preserving effect of salt solution coupled with the common knowledge of its antiseptic action on putrescible substances. The accurate determination of the prime sanitary importance of salt solutions in connection with a milking machine is unquestionably due to Prof. Stocking.

When care was exercised in connection with the machines he found it was not difficult to produce milk at the first dairy which was of lower germ content than that produced by hand milking. On the other hand it was difficult to accomplish this at the other dairy on account of the unusually low germ content of the milk drawn by hand. The air filters had not been added to the machines at the date of this study.

Stocking and Mason[5] reported additional results from a study of the Burrell-Lawrence-Kennedy machine. They tested the efficiency of lime water and of solutions of borax, of formalin and of salt as a means of keeping the rubber parts in a satisfactory sanitary condition. With the exception of the tests where the rubber parts were kept in a formalin solution the results with the machines were not as good as those obtained at the same time by hand milking. During the progress of these studies the air filters were added to the machines but they were not then as efficient as the forms which were later devised.

The use of a cotton filter in connection with the milking machine was originally suggested by Mr. Loomis Burrell as a means of preventing the rise of moisture into the vacuum pipes and its return at the time the vacuum was

[4]From correspondence with Mr. Loomis Burrell.

[5]Stocking, W. A., Jr. and Mason, C. J. Milking machines. Part I. Effect upon quality of milk. Stoors Agr. Exp. Station Bul. 47. May 1907. Also Storrs Ann. Report. 19: 105–129. 1907.

broken at the close of the milking. In the earlier form of machine the introduction of material from this source was so great that at times the milk was noticeably colored with iron rust. The work of Prof. Stocking pointed out that this was also an important source of bacterial contamination and the main suction filter was an immediate result. The relief filters for the purpose of removing the germs from the air before it entered the machine came later as a logical extension of the same idea.

The introduction of these filters, which removed the germs from the inflowing air in proportion to their efficiency, was the second important step in the development of the sanitary milking machine. Later progress has consisted mainly in perfecting the ideas embodied in the application of the salt solution and the cotton filter.

Hastings and Hoffman[6] studied the germ content of milk obtained with the Burrell-Lawrence-Kennedy machine and contrasted it with the milk drawn by hand from other cows. This milk was drawn by hand into a 12-inch pail. The rubber parts of the milking machine were kept in lime water. The resulting numbers showed rather wide fluctuation in the germ content with both methods but on the whole were rather in favor of the machine. The keeping quality of the milk obtained was not influenced by the manner of milking. Woll and Humphrey[7] made careful tests of the same machine for twenty months with twenty-nine cows to determine its efficiency, economy and influence as used experimentally and by practical dairymen in Wisconsin. They concluded that "the success of the milking machine will depend largely upon the man operating the machine and on his attitude toward milking machines. If the machine is given a fair trial and the directions of the manufacturers are carefully followed the machine milking will, as a general rule, be a success, at least to the extent of approximat-

[6] Hastings, E. G., and Hoffman, C. Bacterial content of machine-drawn and hand-drawn milk. Wis. Agr. Exp. Sta. Ann. Rept. **24**: 213–222. 1907. See also *Centbl. Bakt. u. Par.*, II, **22**: 222-231. 1908.

[7] Woll, F. W., and Humphrey, G. C. Milking machine experiments. Wis. Agr. Exp. Station Bul. 173. Feb. 1909.

ing the results obtained by good hand-milkers and perhaps even improving upon those secured by general farm help."

Mairs[8] directed his attention principally to the mechanical side of the milking machine and to the effect upon the cows. However, he compared the flavor of the milk, after the lapse of some days, when drawn by the machine and when drawn by hand. He did not observe any difference in the flavor or keeping quality of these two classes of milk.

The bacterial side of the question was studied by Meek.[9] The average germ content of a large number of samples from individual cows milked with the machine was 47,860 per cc. while a large number of composite samples from four or five cows averaged 83,143 per cc. Milk drawn by hand under comparable barn conditions averaged from one-third to one-half of the above numbers.

Haecker and Little[10] gave the results of two years of observation of the workings of a Burrell-Lawrence-Kennedy machine. A large part of their publication is devoted to a discussion of the cost of installation and of maintenance and of the effect of the machine upon the flow of milk. However, several comparisons are given of the germ content of the machine and the hand-drawn milk, when the machine was cleaned in different ways. Cotton filters were used and the rubber parts were kept in lime water at least a portion of the time. The results obtained with the milking machine did not compare favorably with those from the hand milking except when the labor expended in cleaning the machine was such as to make the milking machine of doubtful economy in practice.

Price[11] studied the Burrell-Lawrence-Kennedy machine for 18 months as it was used under ordinary conditions. His at-

[8] Mairs, T. I. Test of a mechanical cow milker. Penn. Agr. Exp. Sta. Bul. 85. Jan. 1908.

[9] Meek, E. B. Bacterial efficiency of the milking machine. Penn. State Col. Ann. Rep. 1907–8. P. 146–159.

[10] Haecker, A. L., and Little, E. M. Milking machines. Neb. Agr. Exp. Sta. Bul. 108. Dec. 1908.

[11] Price, J. N. Home grown rations in economical production of milk and butter. Tenn. Agr. Exp. Sta. Bul. 80. Jan. 1908.

tention was principally directed to the effect of the machine upon the milk flow. He found that this was not markedly affected. He also stated that a high grade of milk was secured but did not give the conditions under which it was secured nor the data upon which his judgment of its quality was based.

STUDIES AT THIS STATION

MACHINES USED

The Globe cow milker (Plate III, fig. 1), which was first tested, was made by the Rockhill Foundry Co., at Roanoke, Va. The machine was exhibited at the New York State Dairymen's Association meeting in Binghamton in December, 1905, and at the Syracuse meeting of the New York State Breeders' Association in January, 1906. It was installed in the Station barn in March, 1906, and used somewhat irregularly until near the end of the year. The irregularity of operation was due to the fact that the vacuum pump and other accessories frequently got out of order.

This machine was not a success. Aside from the mechanical defects above referred to there were several cows which it did not milk in a satisfactory manner, in some cases failing to remove from the udder more than one-half of the milk. As will be seen later the quality of the milk delivered by this machine when it was run according to the directions of its makers was extremely poor. Moreover the extra labor required to care for the machine more than offset the time saved in the milking process.

In 1907 the Burrell-Lawrence-Kennedy cow milker (Plate III, fig. 2), manufactured by D. H. Burrell & Co., at Little Falls, N. Y., was installed and has been studied from that date to the present time. The principles of operation of this and the Globe machine are quite similar. In each the actual milking is accomplished by producing a vacuum at the end of the teat. A rigid teat cup with a soft collapsible upper edge for preventing the entrance of air surrounds and gently supports the teat and receives the milk which flows from the teat. The

four cups which are applied to each cow are connected by short rubber tubes to the teat cup connector, as shown in detail for the Burrell-Lawrence-Kennedy machine (Plate IV, fig. 2), and a larger tube conducts the milk from this to the pail. Two cows are connected to a single pail. The vacuum is furnished by a large pump and its application to the udder is made intermittent by a mechanical device, the pulsator piston, which is placed at the top of the pail.

In using the machine the vacuum is applied to the teats 40 to 60 times per minute. After each application air is allowed to enter the teat cup, the curtain at its upper end relaxes and the teat fills with milk. Up to March, 1909, this air was supplied through relief openings at the end of the teat cup connectors and through an opening on the pulsator head (Plate IV, fig. 2). The machine used after this date had no relief openings on the pulsator head.

During the past two and one-half years the Burrell-Lawrence-Kennedy machine has undergone numerous improvements at the hands of its makers. It has been necessary to test the influence of the more important of these changes so that our final results would represent the machines actually upon the market. While the milking machine will undoubtedly continue to be improved it is believed that the principles of management here outlined will continue to apply.

TECHNIQUE

A statement of the conditions under which the tests were conducted is necessary to a comprehension of the results and is here presented. The barn conditions were made to approximate as closely as possible those of a good farm dairy and as has already been noted the machine was run in accordance with the directions of the manufacturers except in so far as it was necessary to vary the conditions in testing the individual factors. These variations will be noted in connection with the experiments where they occurred.

Stable conditions.— There are approximately 5 sq. ft. of window surface and 370 cu. ft. of air space for each cow, addi-

tional air being supplied by the King system of ventilation. The ceiling and walls are smooth and of matched lumber, the lower 42 inches of the walls being surfaced with galvanized iron. The mangers and floors are of cement but the cows stand on wooden platforms and are bedded with sawdust. They were in Drown stalls, an arrangement which is not highly satisfactory for the operation of the milking machine on account of the latitude for movement allowed the animals.

Feeding.— The grain is fed before milking with an interval of about 10 minutes in the morning and 30 minutes in the evening, the hay at noon and the silage after the milking at night and morning.

Care of the cows.— The cows are curried thoroughly with comb and brush each forenoon, particular attention being given to their sides, flanks and udders. Twenty to thirty minutes before milking in the morning they are brushed with a broom and about thirty minutes before milking at night they are gone over lightly with comb and brush. The udders were not clipped except that on some cows the long hairs which were pulled by the teat cups were removed.

Method of cleaning machines.— The Globe machine, before noon each day, was scrubbed with bristle brushes in a sal soda solution and rinsed in cold water. The metal parts were subjected to flowing steam for 5 to 8 minutes. After milking at night it was rinsed in cold water, then in a solution of sal soda and hot water and again rinsed in cold water. These rinsing solutions were drawn through the rubber parts by means of the vacuum pump.

The Burrell-Lawrence-Kennedy is rinsed after milking in the same way as the Globe machine but instead of the daily scrubbing the rubber parts and the teat cups are immersed in a 10 per ct. salt solution between milkings. All the metal parts except the teat cups are washed and with the exception of the pulsator piston are thoroughly steamed daily and once a week the rubber parts and teat cups are also scrubbed in a sal soda solution.

Salt solution.— The brine solution in which the tubes and teat cups are held between milkings contains approximately one part of salt to ten parts of water, the salt solution being renewed each week. About 50 quarts are needed to immerse the parts necessary for a dairy of 26 cows. Before being used these rubber parts and teat cups are rinsed with water to remove the salt.

Sampling.— The Globe machine delivered the milk of two cows into a single pail and the samples were taken from this mixed product as it was being emptied. (See Plate III, fig. 1.) Samples of hand-drawn milk were made comparable with those from the machine by mixing the product of two cows which had been milked into a 13-inch open pail. The Burrell-Lawrence-Kennedy machine delivers the milk of each cow separately and samples were taken from the milk of each cow as it was being poured from the milking machine. (Plate IV, fig. 1.) Unless otherwise stated the samples were taken from the product of the first pair of cows at each milking.

The details of the handling of the machines and the general barn management were under the personal supervision of one of us (S), who was present during the experimental runs of the machine in practically all cases. The samples for bacteriological examination were all taken personally by another of us (W) and full notes made as to the actual conditions under which the tests were made.

Plating and incubation.— The samples were taken to the laboratory and the plating completed within an hour. The medium used was as follows:

Agar	15 grams
Peptone (Witte)	10 grams
Lactose, c. p.	10 grams
Beef extract (Liebig)	5 grams
NaCl	5 grams
Water (distilled)	1000 grams

The reaction was adjusted to 1.5 per ct. normal acid to phenolphthalein. This medium was chosen so that the plates

could be held long enough for the lactic acid colonies to develop. On account of the great fluctuation in germ content four dilutions were made from each sample drawn by hand and by the Globe machine. Only three dilutions, plated in duplicate, were made from the product of the Burrell-Lawrence-Kennedy machine. All of the plates were held for 5 days at 23° C. and counted under a lens magnifying four diameters.

In the work with the Globe machine duplicate plates were prepared on standard lactose gelatin but the making of these plates was not continued since the development of liquefying colonies prevented an incubation sufficiently long to allow for a growth of all the acid forms.

PROBLEMS STUDIED

While it is true that each step in the handling of a milking machine has an important bearing upon the quality of the milk produced, there are certain steps which are of maximum importance. In the years during which the milking machine has been under observation the aim has been to find the critical points where attention to details would bring the maximum returns for the minimum amount of effort on the part of the dairymen. The fact had been constantly kept in mind that it is the aim of the progressive dairyman to produce clean milk and to produce it with a minimum expenditure of labor.

There is no question but that the point where the average user of a milking machine can make the maximum improvement at the minimum cost is by a careful attention to the keeping of the rubber parts in a solution of salt or some similar substance.

Conditions where brine is not used.—The determining factor which has hindered the progress of the earlier types of milking machines was the inability to secure milk of a proper keeping quality. Harrison[12] in his study of the Thistle milking machine found that the keeping quality of the machine-drawn milk was much inferior to that of milk drawn by hand. He also found that the germ content of the machine-drawn milk was about

[12]See footnote 1.

fifteen times as great as that of milk drawn by hand under comparable barn conditions.

Since the bacteria are directly responsible for the ordinary changes in milk and their numbers can be determined with a fair degree of ease and accuracy, we have used the numbers present as a convenient measure of the quality of the milk. While not perfect, this is at present the most satisfactory available measure, with fresh milk, of the sanitary conditions which have surrounded its production.

Our results with the Globe milking machine give the germ content of the milk where the machine was carefully washed each day but the rubber parts were not kept in brine. In this test four cows were selected and at each milking two were milked by hand and two with the machine. Each pair of cows was milked alternately by hand and by the machine so that the conditions of hand and machine milking were made as nearly alike as possible. Composite samples representing the milk of two cows were examined in each case. A representative portion of these results is shown in Table I.

TABLE I.— COMPARATIVE GERM CONTENT OF MILK DRAWN BY GLOBE MACHINE AND BY HAND.

1906.	Cow.	Germs per cc. in milk: Machine drawn.		1906.	Germs per cc. in milk: Hand drawn.	
		A. M.	P. M.		A. M.	P. M.
Aug. 20......	1 & 2	680,000	349,750	Aug. 24...	9,520	....
" ".......	3 & 4	625,500	762,000	" "...	15,150	....
" 21......	1 & 2	835,000	770,500	" 25..	*374,500	5,800
" ".......	3 & 4	718,500	452,500	" "	58,000	16,100
" 22......	1 & 2	962,000	675,500	" 26..	11,050	10,870
" ".......	3 & 4	593,500	1,700,500	" "...	17,350	20,330
" 23......	1 & 2	864,000	639,600	" 28..	74,000	2,250
" ".......	3 & 4	585,000	1,113,500	" "...	43,000	6,400
" 27......	1 & 2	....	748,500	" 29...	....	6,650
" ".......	3 & 4	....	798,500	" "...	....	3,620
" 29......	1 & 2	312,500	....	" 30...	8,500	5,600
" ".......	3 & 4	357,000	....	" "...	13,120	5,550
Average......	....	653,300	731,785	Average..	24,969	8,317
Gen. av......	....	692,542		Gen. av..	16,643	

*Not in average.

The above table shows that the machine milk contained about 43 times as many bacteria as that drawn by hand.

It is also interesting to observe that under these conditions the simple rinsing which the machine received after the evening milking was practically as efficient as the laborious washing and steaming which were given it after the morning milking.

It will be noted that the germ content of the hand-drawn milk in the morning is more than three times as great as that obtained at night. This is undoubtedly due to the superficial manner in which the cows were cleaned and to the dust in the air as the result of their being cleaned and fed immediately before milking in the morning as was explained under the heading of technique.

There is no known reason for the extremely high numbers found in the hand-drawn milk on the morning of August 25. Since it was so out of keeping with the other results it was given in the table but not included in the averages.

The data in the above table were restricted to the period including August 20 to 30 since it was during this time that samples were taken both morning and evening and the experimental conditions for accurate comparative work were at their best. During the study of this question with the Globe machine there were examined 39 samples of machine-drawn milk having an average germ content of 81,100 per cc. and 36 samples of hand-drawn milk with an average content of 16,800 per cc.

In these studies with the Globe machine the results obtained from its use were contrasted with those obtained by milking by hand into a 13-inch open pail under comparable barn conditions. It soon became evident that as a basis of comparison the results obtained with an open pail were of little use. This was partly because there was little constancy in the results obtained with an open pail and largely because the factors which govern the results obtained by the two methods of milk-

ing are entirely different. With the open pail the germ content depends mainly on the degree of cleanliness of the individual cow while with the milking machine the results turn mainly on the germ content of the rubber tubes through which the milk is conducted.

From this point the comparison between the results obtained from hand and machine milking was discontinued and the study was directed toward the influence of variations in handling the machine upon the germ content of the resulting milk. Parallel with this study of the effect of variations in handling upon the product of the milking machine a study is being made of the influence of various factors upon the germ content of hand-drawn milk. It is evident that the production of milk with a low germ content will be accompanied by an increased cost of production. When both of these methods of milking are reduced to standard conditions a comparison of the cost of production of milk of approximately the same germ content by each method will be of decided economic interest.

In the preceding work the examination of the effect of the Globe machine was restricted to the first pair of cows to which the machine was applied at each milking. This was done to avoid the influence of accidental contamination of the machine in milking other cows.

The marked increase in germ content which the milk received in passing through the machine suggested that the machine in turn might be partially cleaned by being used in the milking process. This point was determined by examining the milk of three successive pairs of cows which were milked by the same Globe machine. The results of these examinations are given in Table II.

TABLE II.—GERM CONTENT WITH SUCCESSIVE PAIRS OF COWS MILKED BY GLOBE MACHINE.

Date, 1906.	Germs per cc. in milk from different cows.		
	First pair.	Second pair.	Third pair.
Nov. 14	38,920	27,570	17,500
" 15	66,870	48,330	34,600
" "	70,000	47,870	41,000
" 16	83,000	41,850	17,520
" "	78,750	46,960	19,150
" 17	54,200	29,600	14,970
" 24	65,000	28,830	*69,660
" 26	20,330	19,660	3,500
" 27	22,330	12,000	10,330
" 28	10,830	10,830	†21,061
" 30	11,830	12,500	5,330
Average	47,460	29,633	23,156

*Teat cups kicked off and pulled from connector.
†Teat cups fell on the floor just before last cows were milked.

In practically all of the above tests, except those in which accidents occurred to the machines during the milking, there was a progressive reduction in the amount of contamination which passed into the milk of successive pairs of cows. This brings out clearly the fact that the scrubbing and steaming to which the machine was subjected each day was not sufficient to keep the rubber parts in a sanitary condition. Even after having milked six cows the machines were not sufficiently clean to deliver milk of a satisfactory quality.

The Globe machine when handled in accordance with the direction of its makers was a failure, not only because it did not milk the cows in a satisfactory manner, but also because it so highly contaminated the milk. This latter fact is shown very clearly by the foregoing data on the bacterial content but it was quite as evident in the keeping quality of the milk and in its quality when used for cheese making.[13] During the

[13] Harding, H. A., and Prucha, M. J. The bacterial flora of cheddar cheese. N. Y. Agr. Exp. Sta. Tech. Bul. 8, p. 162. 1908.

warmer portion of the year it was difficult to keep the milk sufficiently sweet to pass through a centrifugal separator after 48 hours even when held in cold running water.

Influence of salt brine.— The makers of the Burrell-Lawrence-Kennedy machine directed that the teat cups and the rubber parts be immersed in a 10 per ct. salt solution between milkings. With this machine the milk from each cow was kept separate and samples were taken accordingly. The machine-drawn milk from two cows was sampled March 6–20 inclusive when the teat cups and rubber parts were kept in brine between milkings. Once each week they were scrubbed in a sal-soda solution before being returned to the salt solution. From March 21 to the close of the test the entire machine was carefully cleaned each day but no part of it was placed in the salt solution. The results of the bacteriological examinations are given in Table III.

TABLE III.—GERM CONTENT WITH THE B-L-K MACHINE WHEN THE RUBBER PARTS WERE AND WERE NOT KEPT IN A SALT SOLUTION.

1908.	Rubber parts in brine.		1908.	Rubber parts not in brine.			
		Germs per cc. of milk.		Ruth.	Millie D.	Bess.	Nora.
				Germs per cc. in milk.			
March 6	Bess	8,590	April 14	9,500	18,500	45,400	39,000
	Nora	1,400	" 15	181,500	708,000	236,200	89,500
" 9	Bess	*176,620	" 16	56,000	60,750	31,400	108,750
	Nora	74,520	" 17	220,000	468,300	350,000	288,500
" 11	Bess	5,250	" 20	67,500	406,250	236,000	139,250
	Nora	30,240	" 21	11,250	15,250	19,750	150,250
" 17	Bess	2,710	" 22	32,500	34,000	30,000	175,500
	Nora	1,940	" 23	95,250	79,000	110,500	138,000
" 19	Bess	7,250	" 24	459,500	351,000	445,750	464,000
	Nora	14,200		....	....	....	....
" 20	Bess	7,500		....	....	....	....
	Nora	34,350		....	....	....	....
Average	....	17,086		126,000	237,900	167,000	177,000
General average	....	....			188,580		

* Omitted in computing the average.

It will be seen from the table that when the salt solution was used the germ content of the milk, while fluctuating considerably, had an average germ content of approximately 17,000 per cc., omitting from the average the single very high number found on March 9.

After the rubber parts had been 24 days out of the brine and had time to become a fair illustration of tubes handled in this way the series of examinations, April 14–24, gave an average of 188,380 per cc. This was approximately ten times the germ content found with the same machine when the salt solution was used.

As the very nature of the influence which was being measured prevented a close comparison of the tubes kept in and out of the brine it was the intention to test the effect of the machine shortly after the teat cups and rubber parts had been again placed in the salt solution. Unfortunately, in connection with this change, the cotton filters, to be later described, were also inserted in the machine. In 20 tests of the milk which were made between April 27 and May 1 the average germ content was 2600 per cc. While filters were responsible for a portion of this reduction the major part of it was undoubtedly due to the action of the salt solution. The relative importance of these two factors, cotton filters and salt solution, is brought out in Table V. (See page 80.)

Importance of care in placing tubes in brine.— It will be noted in the results of our studies with a brine solution that, occasionally, extremely high counts were obtained in individual cases. This was so pronounced in the case of some of our preliminary work that the cause was sought in the presence of air in the rubber tubes while in the brine.

As a matter of convenience and to obviate the necessity of assembling the parts after taking them from the brine the teat cups and the accompanying rubber parts were left connected when placed in the salt solution. Unless care was exercised in the act of immersing them air was inclosed in the tubes and the brine did not have free access to all parts of

the tubes and according could not be expected to exercise fully its restraining influence on the bacterial life.

In the preliminary work the placing of the tubes in the brine was intrusted to the men who had charge of the machines. An inspection of the tubes showed that they contained air in considerable quantities. Thereafter, the condition of the tubes was inspected by one of us before 10 o'clock of each day on which samples were to be collected at the night milking and the air, which was practically always found in the tubes, was expelled. Simultaneously with this increased care there was a marked decrease in the fluctuation of the germ content of the milk although high counts were occasionally obtained as shown in the tables.

Later, an attempt was made to measure the effect of allowing air to remain in the tubes. In this test the two machines which were used were supplied with cotton in the filter cups and were handled alike in all respects except that on each night two cows were milked with rubber parts in which the aid had purposely been inclosed while in the brine tank while the tubes used in milking the other two cows had been carefully filled with brine after the preceding milking. Each cow was milked an equal number of times with tubes which had been handled in each of these ways.

The resulting data are given in Table IV.

TABLE IV.— EFFECT OF INCLOSED AIR IN THE TUBES WHILE IN THE SALT SOLUTION.

1909.	Air left in tubes.				Air out of tubes.			
	Both cows milked at once.		Cows milked separately.		Both cows milked at once.		Cows milked separately.	
	Prin-cess A.	Millie F. B. B.	Nora D.	Carey of S.	Prin-cess A.	Millie F. B. B.	Nora D.	Carey of S.
	Germs per cc. in milk.							
June 21..	......	......	......	1,500	1,780	930	......	....
" 22..	10,720	4,260	......	......	......	......	2,700	1,760
" 23..	1,400	16,270	......	......	......	......	3,750	1,790
" 24..	6,420	3,850	......	......	......	......	3,660	1,750
" 25..	......	......	1,600	2,000	2,370	700	......	....
" 26..	1,730	2,430	......	......	......	......	1,620	1,450
Av....	5,070	6,700	1,600	1,750	2,070	660	2,930	1,690
Gen. av..	4740				1990			

The data in the above table came as a surprise, since, if we eliminate the two high counts on May 28 and 29, there is practically no difference in the results obtained by the two lines of treatment.

On one hand is the observed marked improvement which immediately followed the careful removal of all air from the tubes at the beginning of our work and on the other is the failure of larger numbers of bacteria to appear in the milk when the air was purposely allowed to remain in the tubes. In the face of such conflicting evidence positive conclusions can not be drawn but it does seem a logical conclusion that since the action of the brine was so important in reducing the germ content its free access to the entire surface of the tube should be followed by beneficial results.

FILTERS

While the use of brine for holding the teat cups and rubber parts between milkings very markedly improved the quality of the milk as shown by the reduced germ content, even under

fairly good barn conditions milk with a germ content of 20,000 to 30,000 per cc. marked the practical limit of this improvement.

It will be remembered that after each pulsation of the machine air is admitted to release the vacuum and this air being drawn from beneath the cow and in close proximity to the bedding must carry with it dust and bacteria in considerable numbers. The origin of the cotton filter has been discussed in connection with the work of Stocking (see page 63) and the first machines furnished us by the makers were equipped with the small cotton filters shown in Plates V and VI. During the period in which this study has been conducted the filters have undergone marked improvement and the importance of the principle of filtering the air entering the machine is well illustrated by the variations in germ content which have followed the use of these various filters.

Test of small filters.— On the model first studied, machines Nos. 1287 and 1288, the relief filter on the pulsator head was the same size as those on the teat connectors and all were quite small as is shown in Plate V, fig. 1, and Plate VI, fig. 3. In these plates the blocks opposite the filters indicate the cotton containing capacity of the filter cups. The main suction filter (Plate V, fig. 1) was cast in the body of the pulsator at the base of the nipple which joins the milker to the stanchion hose. It will be noted from the plate that it would accommodate only a thin layer of cotton.

In the test of these machines the teat cups and rubber parts, with the exception of the stanchion hose, were kept in a 10 per ct. salt solution. The only variation in handling was the insertion of cotton in the filter cups during a part of the tests and the omission of cotton from the filters at other times. The milk of three successive pairs of cows was tested to determine whether there was such a progressive change in the germ content of the milk as was noted in connection with the Globe machine.

The results of this examination are given in Table V.

TABLE V.— GERM CONTENT OF MILK FROM B-L-K MACHINE WHEN THE RUBBER PARTS WERE KEPT IN BRINE.

RESULTS WITH SMALL COTTON FILTERS. VACUUM BROKEN AT STANCHION COCK.

1907.	Suction filter side.			Other side.		
	1st cow.	3d cow.	5th cow.	2d cow.	4th cow.	6th cow.
	Germs per cc. of milk.			Germs per cc. of milk.		
Mar. 23	27,530	11,360	15,000	15,330	14,000	14,060
" 26	18,200	44,600	10,000	5,700	7,400	2,900
" 27	7,200	14,700	5,700	6,000	5,900	9,400
" 29	4,000	5,200	2,700	2,700	4,900	1,800
April 1	23,400	17,700	87,000	17,900	14,100	1,400
" 3	9,100	20,200	21,500	9,300	10,700	4,000
" 4	12,000	5,600	19,400	5,600	14,000	2,200
" 6	64,400	22,200	29,700	8,900	10,700	9,600
Average	20,730	14,840	24,000	8,930	10,210	5,730
Gen. average		19,856			8,290	

RESULTS WITHOUT COTTON FILTERS. VACUUM BROKEN AT STANCHION COCK.

1907.	Suction filter side.			Other side.		
	1st cow.	3d cow.	5th cow.	2d cow.	4th cow.	6th cow.
	Germs per cc. of milk.			Germs per cc. of milk.		
Mar. 22	228,000	72,000	27,200	......	......	......
" 25	7,600	29,300	3,400	5,200	4,800	7,700
" 28	27,200	18,400	28,700	18,400	19,100	29,000
" 30	87,300	23,700	17,900	5,200	8,900	1,800
April 2	18,300	33,000	22,900	1,300	8,300	17,400
" 8	33,950	75,000	83,750	11,150	12,650	8,250
" 9	26,500	29,200	33,800	9,850	6,730	14,600
" 10	126,500	29,000	156,000	16,800	28,150	30,300
Average	69,420	38,700	46,700	9,700	12,660	15,590
Gen. average		51,600			12,650	

Several interesting things are brought out by the results in this table. In the first place there is no evidence of the progressive reduction in the germ content which was observed on successive cows in the study of the Globe machine. Accordingly later observations were confined to the first pair of cows milked by a machine thus reducing the danger of accidental contamination to a minimum.

Again there is a marked difference in the germ content of the milk received into the two sides of the pail and this difference is very pronounced both with and without the presence of the filters.

Contrasting either side of the pail when it is run with and without the filters it is seen that the presence of the filters resulted in a marked reduction in the germ content. This is particularly marked on the side under the main suction filter where the averages were 19,856 per cc. when the cotton was placed in the filter cups and 51,600 per cc. where the cotton was omitted from the machine.

Inefficiency of the small suction filter.— A possible explanation of the observed differences in the germ content of the milk from opposite sides of the pail might be the germ content of the respective cows' udders. However, the uniformity of the difference in the product of three successive pairs of cows renders this explanation highly improbable.

Carefully secured samples of the last milk from the udders of these six cows were plated. The average germ content of those milked into the suction filter side of the machine was 556 per cc. while those milked into the opposite side of the machine had an average germ content of 1293 per cc. These differences are small and are in the opposite direction from the differences observed with the milking machine and therefore do not aid in explaining these latter differences.

An inspection of Plate V will show that the main suction filter is not placed in the center of the pail but at one side and over the part receiving the milk of one cow as indicated in Table V. When the milking of two cows has been completed it was the custom to close the stanchion cock and disconnect the stanchion hose at this point in order to admit air to the pail so that it could be opened. This sudden inrush of air through the four-foot stanchion hose carried with it such dust and bacteria as might be in this hose and in the air except as they were removed by the cotton in the main suction filter.

It will be remembered that it was the observed introduction of iron rust and other foreign material in this way that originally led to the adoption of the filter at this point.

If the variations in the germ content on the two sides of the pail noted in the previous table were really due to the inefficiency of the cotton filter to successfully handle this sudden inrush of air these variations in the germ content of the milk of the two sides of the pail should disappear if the air for destroying the vacuum was introduced from some other source. Accordingly the test with and without the presence of the cotton in the filter was repeated in the same manner as before except that in this experiment at the close of the milking after the stanchion cock was closed the air was allowed to enter gently through the teat cups.

The results of these observations on four cows and using two milking machines are given in Table VI.

TABLE VI.— GERM CONTENT WITH B-L-K MACHINES WHEN VACUUM WAS BROKEN THROUGH THE TEAT CUPS.

	Without cotton filters.					With cotton filters.			
	Machine No. 1287.		Machine No. 1288.			Machine No. 1287		Machine No. 1288.	
	Filter side.	Other side.	Filter side.	Other side.		Filter side.	Other side.	Filter side.	Other side.
	Germs per cc. in milk.					Germs per cc. in milk.			
June 19	26,010	77,500	19,850	18,098	June 7	3,710	8,360	15,510	13,950
" 20	5,280	2,530	19,810	19,000	" 10	1,830	3,820	6,830	3,300
" 21	35,250	32,850	17,100	18,500	" 11	2,960	1,250	2,320	2,440
" 22	52,150	9,170	7,530	8,990	" 12	2,970	1,680	1,720	4,620
" 24	10,210	5,270	9,240	12,900	" 13	3,850	2,240	4,860	3,600
" 25	16,000	4,410	4,310	9,680	" 28	4,640	680	*	*
" 27	8,760	1,360	7,470	22,930	" 29	16,160	6,950	16,230	10,860
July 2	11,190	44,330	16,050	18,230	July 1	7,880	2,750	10,660	14,350
					" 3	5,760	1,380	5,190	7,790
Average	21,358	22,177	12,670	16,040		5,528	3,234	7,915	7,613
Gen. Av.	10,758		7,177			4,383		7,764	

* Teat cups dropped; colonies overran the plates.

In these tests where the strong inrush of air at the close of the milking was prevented, the resulting germ contents bear no distinct relation to the location of suction filter. Under these circumstances the thin layer of cotton in the suction filter sufficed for all the duty laid upon it and with the cotton in place the results are both very low and quite constant. The highest recorded germ content in 34 tests with the cotton filters is 16,230 per cc. with an average of 5,840 per cc. Where the cotton filters were not used the average of 36 determinations was 18,060 per cc. with a maximum of 77,500 per cc.

It is interesting to observe that on June 28 when the teat cups were accidentally dropped on the floor the milk contained so large a germ content that the colonies on the plates were too numerous to count.

Modification of the filter cups.— Up to July, 1907, the Burrell-Lawrence-Kennedy machine was used without any changes in its manner of construction. At that date the filter cups were replaced by new ones which were much larger, much easier to clean and more easily packed with cotton. Plate V, fig 2, and Plate VI, fig. 2, show the increased size of these filters over the ones first used. The main suction filter on the pulsator base between the pail and the nipple for the stanchion hose (Plate V, fig 2) is approximately 11 times larger than the one originally furnished with the machine (Plate V, fig. 1). The relief filters on the pulsator head and those on the teat cup connectors as shown in Plate VI, figs. 2 and 3, are approximately 9 times larger than those previously tested.

Our results given in Table V show clearly that the former suction filter was inefficient and to obtain milk with a small germ content it was desirable to release the vacuum at the close of the milking process by allowing the air to flow in slowly through the teat cups. This was undesirable in practice because of the time lost in the process and also the fact that unfiltered air with its accompanying quota of bacteria was being admitted to the pail. The efficiency of the new suction filter was tested by breaking the vacuum on alternate nights in the two different ways. In all of these tests the teat cups and

rubber parts were kept in brine and the filter cups were carefully filled with cotton before each milking. The results are given in Table VII.

TABLE VII.—GERM CONTENT OF THE B-L-K MACHINE USING AN EFFICIENT SUCTION FILTER, AND KEEPING THE RUBBER PARTS IN BRINE.

1908.	Vacuum broken through teat cups.				1908.	Vacuum broken through stanchion hose.			
	Machine No. 2716.		Machine No. 2437.			Machine No. 2716.		Machine No. 2437.	
	Filter side.	Other side.	Filter side.	Other side.		Filter side.	Other side.	Filter side.	Other side.
	Germs per cc. in milk.					Germs per cc. in milk.			
Jan. 29....	3,110	6,740	2,070	5,630	Jan. 30.....	3,660	520	1,080	2,050
Feb. 4....	4,300	610	1,350	750	" 31.....	5,080	*.....	2,970	1,070
" 6....	21,400	1,650	1,340	890	Feb. 3.....	4,100	1,610	......	......
" 13....	......	......	2,820	2,050	" 5.....	1,980	850	1,620	7,390
" 15....	......	......	2,780	520	" 7.....	4,840	6,560	810	890
" 17....	......	......	1,060	1,660	" 14.....	......	......	2,790	1,520
" 19....	......	......	1,680	440	" 18.....	......	......	990	1,290
Average....	9,600	3,000	1,870	1,710		3,930	2,380	1,710	2,200

* Plates lost by contamination.

These results indicate that the larger suction filter is capable of removing the germs from the air which rushes in at the time the stanchion hose is removed from the stanchion cock, since the germ contents of the two sides of the pail when the air is admitted in this way are practically equal.

The average germ content in this experiment is actually lower when the air is admitted in this manner than when the vacuum is broken through the teat cups but since this difference is mainly due to the high numbers obtained at a single milking (February 6) little stress should be laid upon this fact.

While the difference in time and accompanying possibility of change in the barn conditions precludes a close comparison, it is significant that while the average germ content obtained with the original small filters was from 7,000 to 10,000 per cc.

No treatment. Inoculation, no lime Lime, no inoculation. Inoculation and lime.

PLATE II.— WEEDS AND HAY FROM EQUAL AREAS ON ALFALFA PLATS WITH DIFFERENT TREATMENT.

FIG. 1—GLOBE MILKING MACHINE.

FIG. 2.—BURRELL-LAWRENCE-KENNEDY COW MILKER.

PLATE III.

Fig. 1—Method of Delivery of Milk by B-L-K Machine.

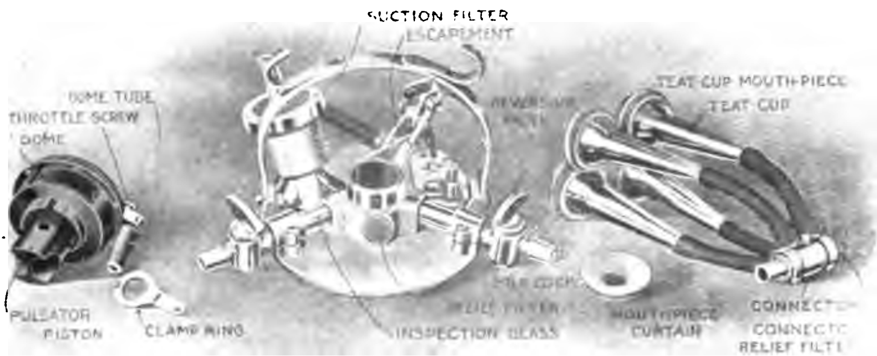
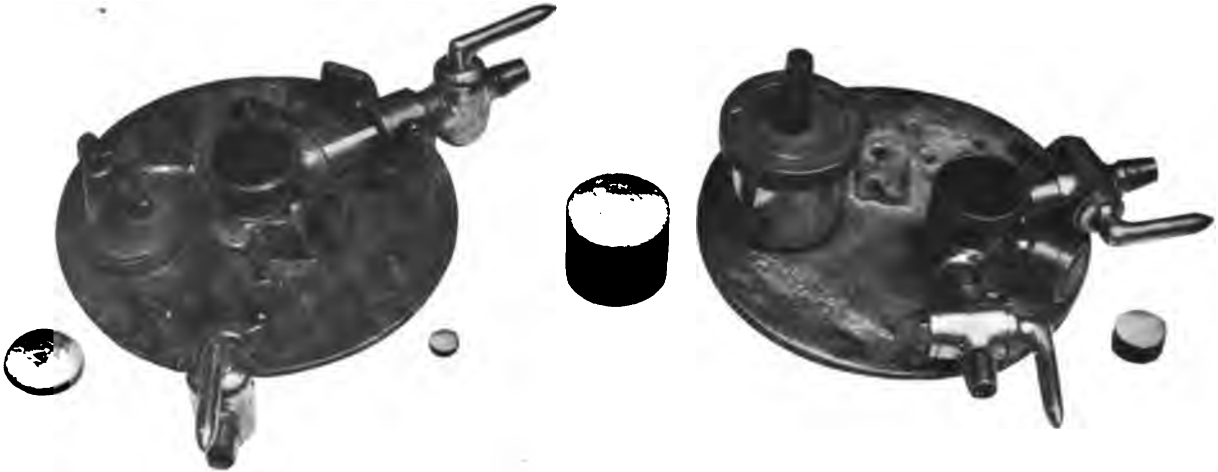


Fig 2.—Details of Construction of B-L-K Machine.

PLATE IV.



1 2

PLATE V.— Two Styles of Pulsator Head of B-L-K Machine: Blocks Show Sizes of Filters.

1, Machine No. 1287 or 1288; 2, Machine No. 2716.

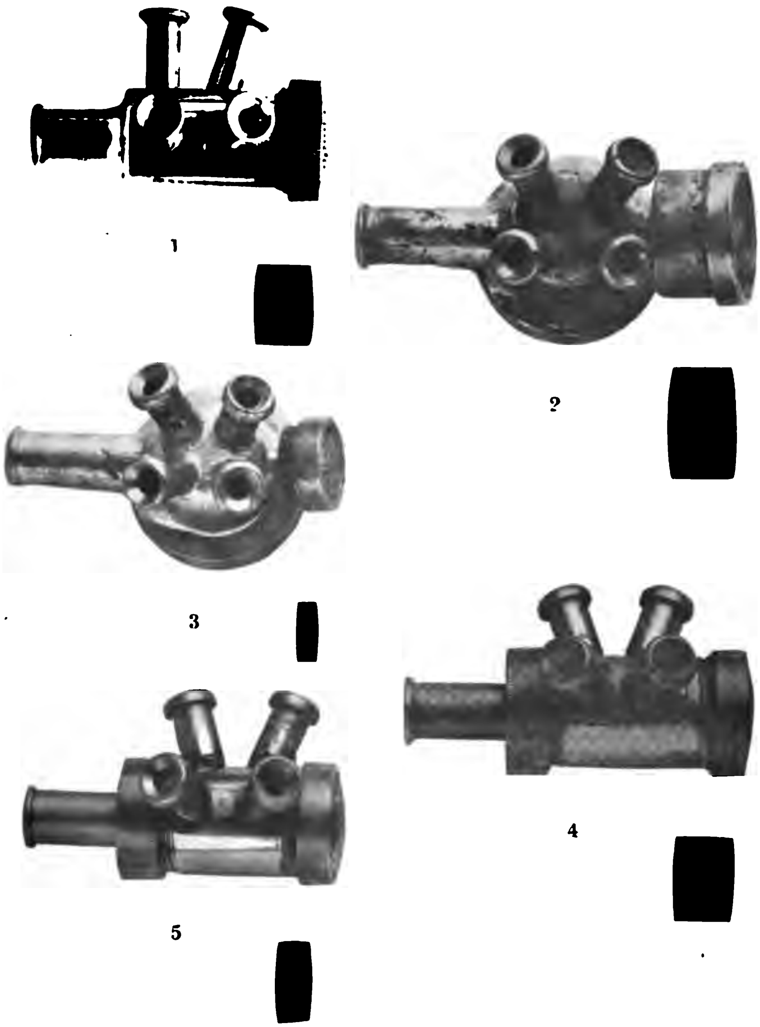


PLATE VI.— Various Styles of Teat Cup Connectors of B-L-K Machine: Blocks Show Sizes of Filters.

First Form, 3; Next Form, 2; Third Form, 5; New Forms, 1 and 4.

the numbers found when using these large filters are distinctly below these figures.

NEW TYPE OF MILKING MACHINE

Late in 1907 there appeared what really amounted to a new type of milking machine. In this machine, No. 2716, no unfiltered air was admitted to the milk chamber, the form of suction filter which had been found to be efficient was retained, and the relief filters were of the form shown in Plate VI, fig. 4. In these latter filters the cup for cotton was nearly twice as deep and twice as wide as in the filters originally furnished, as shown in Plate VI, fig. 3.

A comparative test of the efficiency of this new machine as contrasted with the one originally furnished us was conducted. In this test the machines were handled as nearly alike as possible. Two of the four cows which were used in this experiment were milked by each machine on alternate nights, and each operator used each machine an equal number of times. The teat cups and rubber parts were all kept in the same brine tank and the cotton was carefully adjusted in the filter cups before each milking. The comparative results are given in Table VIII.

TABLE VIII.— GERM CONTENT OF MILK FROM TWO DIFFERENT TYPES OF B-L-K MACHINES UNDER SIMILAR CONDITIONS OF OPERATION.

1907.	Old Machine No. 1288.				New Machine No. 2716.			
	Nora	Bess.	Millie F.	Mabel G.	Nora.	Bess.	Millie F.	Mabel G.
	Germs per cc. of milk.				Germs per cc. of milk.			
Dec. 2	14,300	6,370	.....	.....	.....	.....	5,810	2,840
" 4	.....	.....	8,390	20,060	2,310	1,170	.....	.....
" 5	*2,310	*7,270	.....	.....	.....	.....	*650	*4,710
" 6	.....	.....	14,040	21,920	2,230	1,880	.....	.....
" 7	2,760	1,750	.....	.....	.....	.....	1,210	6,050
" 9	.....	.....	7,210	16,550	1,650	3,420	.....	.....
" 16	.....	.....	11,040	10,130	1,410	1,720	.....	.....
" 17	*4,810	*10,750	.....	.....	.....	.....	*3,040	*7,510
" 18	.....	.....	3,800	5,170	1,080	2,790	.....	.....
" 19	1,460	3,900	.....	.....	.....	.....	9,370	5,400
" 20	.....	.....	1,130	16,140	990	1,990	.....	.....
" 21	2,750	4,630	.....	.....	.....	.....	7,100	720
Average	4,898	5,780	7,600	14,995	1,610	2,160	4,530	4,540
General average	8,340				3,210			

* Teat cups changed before milking.

The results bring out quite clearly the fact that the new type of milker is a distinct improvement over the one which preceded it. Not only is the average germ content with machine No. 2716 distinctly lower than that of machine No. 1288, but what is even more important, the results with its use are subject to far less variation than with the latter one. Of these 28 consecutive determinations with machine No. 2716 not one of them showed 10,000 per cc. and the average of all is less than one-third of that number. It should be noted, however, that these results were obtained in December and it does not follow that as low counts could be obtained with a like regularity in summer.

The practical improvement in the new type of machine was actually greater than was shown by these figures. The filter cups on machine No. 1288 were so small that the proper filling of them was attended with difficulties. After the tubes had

been rinsed free of brine a small amount of water commonly remained in the filter cups and this was hard to remove. This tended to wet the cotton, causing it to mat down and not filter the air properly. Also the bulk of the cotton in the filter was so small that on screwing on the filter cover the cotton was easily entangled and rolled to one side practically destroying the filtering action. By careful attention to details these factors were reduced to a minimum in our work but in practical use they would have been important. On machine No. 2716 the cylindrical filter cups were so much larger that neither of these factors was so troublesome.

Comparison of later forms of relief filters.—On account of the important modifications we thought it best to to test two new machines, Nos. 3157 and 3158. These differed from the preceding form in that they did not have a relief filter on the dome of the milking machine and the relief filters at the teat cup connectors had correspondingly larger openings for the entrance of air. In connection with these machines there were furnished two different forms of relief filters which are shown in Plate VI, figs. 1 and 4. It will be noted from the wooden blocks which indicate the capacity of the filter cups that these were of practically the same size and shape. The difference in the filters lies in the extension of the air chamber in the case of filter 1 in the form of a cone which admits the air into the teat cup connector in front of the openings coming from the forward pair of teats. The filtering cotton was prevented from entering this cone by a perforated sheet of metal. The object of this change was to equalize the milking action on the four teats. The test was intended to determine whether this change in form influenced the filter action when the capacity of the filter remained constant. In this test machines 3157 and 3158 were used on four cows, the conditions being kept as constant and the machines handled as well as possible. Each cow was milked four times with each form of relief filter. The results of these 32 tests are given in Table IX.

TABLE IX.—COMPARISON OF TWO LATE FORMS OF RELIEF FILTERS.

	Filter, Plate VI, fig. 1.				Filter, Plate VI, fig. 4.			
Machine No.	3157		3158		3157		3158	
Cow	Clay B.	Fancy A.	Millie F.	Ham-mond F.	Clay B.	Fancy A.	Millie F.	Ham-mond F.
	Germs per cc. of milk.				Germs per cc. of milk.			
May 28........	22,030	9,790	.....	......	.....	.....	*63,600	2,640
" 29........	.....	.....	3,800	16,620	3,550	9,300	......	......
June 1........	.....	.....	2,550	10,000	2,900	3,330	......	......
" 2........	2,810	3,940	.....	......	.....	.....	4,130	7,140
" 3........	.....	.....	1,620	16,410	3,630	9,610	......	......
" 4........	5,690	15,500	.....	......	.....	.....	3,500	10,500
" 5........	.....	.....	4,150	7,920	4,290	7,490	......	......
" 7........	3,810	6,830	.....	......	.....	.....	2,270	6,700
Average.......	8,580	9,010	3,052	12,737	3,592	7,432	3,300	6,745
Gen. average...	8,345				5,267			

* Not in average.

The results obtained from Millie F. on May 28 are not included in the average because in making the plates the sample met with a slight accident and the results are plainly not in accord with the remainder of the observations.

It will be observed that with three of the cows the results were slightly better on the average with the filter supplied with the cone but this difference was not marked and probably lies within the range of variation which would be experienced in running the machine on two different nights.

Placing cotton in the suction filter only.—The sole objection on the part of the dairymen to placing cotton in the filter cups arises from the fact that this cotton must be inserted carefully before each milking and time is consumed in the process. This was particularly true of machines No. 1287 and 1288 where the care required in properly inserting the cotton was especially trying. With the later models the filter cups have been larger and the difficulties correspondingly less. In view of the marked influence of the suction filter as brought

out on pages 81–84 a test was made of the effect of filling only the suction filter cup with cotton and contrasting this with the results where this cotton was not used. In this test the rubber parts were kept in 10 per ct. brine and the machine, No. 2716, was handled with care in every respect, the only difference being in the presence and absence of cotton in the suction filter. The results of these tests are given in Table X.

TABLE X.— EFFECT OF PLACING COTTON IN THE SUCTION FILTER ONLY.

1908.	Cotton.		1908.	No cotton.	
	Nora.	Bess.		Nora.	Bess.
	Germs per cc. of milk.			Germs per cc. of milk.	
March 5	1,800	6,110	March 6	1,400	8,590
" 7	2,000	1,700	" 9	74,520	176,620
" 12	5,220	4,190	" 11	30,240	5,250
" 13	1,100	3,860	" 17	1,940	2,700
" 16	4,140	6,200	" 19	14,200	7,250
" 18	9,200	5,040	" 21	34,350	7,500
" 23	2,120	9,040			
Average	3,650	5,160	Average	26,110	6,260
General average	4,405		General average	16,185	

These results indicate that the use of cotton in the suction filter alone will markedly improve the quality of the product. This improvement is shown especially in the reduced range of variation in the counts.

The average of the results where no cotton was used has little value on account of the wide variation in the results but this variation is characteristic of the absence of filters, and the average expresses the marked tendency toward higher results. In computing this average the high count from Bess on March 9 was omitted. Her milk entered the side of the machine opposite the suction filter where the absence of the cotton ordinarily had less effect and the high count was un-

doubtedly due to some factor other than the absence of cotton in the suction filter.

These results indicate that where the dairyman does not feel that there is sufficient time to fill all of the filter cups with cotton the maximum benefit will be obtained by filling the suction filter.

Absorbent vs. ordinary cotton in the filter cups.—In some of our earlier work with the milking machine the cotton used in the filter cups was that known as absorbent cotton, it having been treated chemically to remove the oil and other foreign substances. On account of its previous treatment this cotton is much more expensive than the ordinary form and it has some other disadvantages. The difficulty of removing all of the moisture from the earlier form of filter cups has been mentioned and this form of cotton readily absorbed this moisture and tended to mat down and interfere with the passage of air. A comparison was made of the relative filters in efficiency of absorbent and ordinary cotton.

In this, the milking parts were kept in brine, the same man operated both machines, the vacuum was released through the teat cups and the conditions were made as strictly comparable as possible except that at each milking the filter cups of each machine were packed with the two kinds of cotton respectively.

The results from this test are given in Table XI.

TABLE XI.— COMPARATIVE EFFICIENCY OF ABSORBENT AND COMMON COTTON IN THE FILTER CUPS.

1907.	Absorbent cotton				1907.	Common cotton			
	Machine No. 1288.		Machine No. 2437.			Machine No. 1288.		Machine No. 2437.	
	Germs per cc. of milk.					Germs per cc. of milk.			
	Nora.	Bess.	Mabel G.	Millie F.		Nora.	Bess.	Mabel G.	Millie F.
Nov. 11...*	10,100	4,270	2,660	1,020	Nov. 13.....	1,910	5,570	5,180	390
" 12....	7,220	1,060	7,100	650	" 15.....	3,020	3,050	7,060	2,470
" 14....	2,040	420	2,620	930	" 18.....	1,480	790	9,750	1,540
" 16....	740	3,980	5,430	3,470	" 20.....	1,420	2,210	5,110	2,000
" 19....	2,150	2,780	5,750	6,350					
Average....	2,430	2,500	4,720	2,480		1,980	2,980	6,800	1,600
Gen. av.....	3,030					3,340			

*Teat cups fell off while milking.

It will be seen from these results that there was no observable difference with the two kinds of cotton used in these tests. If considerable care had not been taken to remove the moisture before aplying the absorbent cotton the showing would undoubtedly have been markedly in favor of the ordinary kind. On account of its mechanical advantages and markedly lower cost there is every reason why ordinary cotton should be used in the filter cups on a milking machine and so far as these studies have gone there are no known disadvantages in its use.

The count obtained from Nora on November 11 shows the result of the accidental falling off of the teat cups during the milking process. Since these results were obtained as the result of abnormal conditions of milking they were not included in the averages.

MINOR FACTORS.

While the most important points in the handling of the milking machine seem to group themselves logically around

the subjects of the use of brine and of air filter there are other minor factors which should be considered. Our observation on the influence of two of these is here presented.

Carrying the pail with the top off.—It was observed that there was a marked tendency on the part of the milkers to carry the milking pail into the barn with the top off, since in this way the weight was more easily distributed although the pail was not excessively heavy when the top was on. In our work the tops were put on the pails immediately after they had been steamed and were kept carefully in place until the time for milking. In the present test, in one case the milker carried the pail in one hand and the top in the other from the wash room to the stable and in between the two cows which were to be milked—a distance of 30 to 50 feet—and in the other case the pail was carried with the top on the pail. It was intended that the exposure of the pails in this way should be approximately equal to that experienced in the regular manipulation in the barn. The results of 20 counts of milk produced under each set of conditions is given in Table XII.

TABLE XII.—EFFECT ON GERM CONTENT OF CARRYING PAIL WITH THE TOP OFF.

1908.	Top on pail				1908.	Top off pail.			
	Machine No. 2437.		Machine No. 2716.			Machine No. 2437.		Machine No. 2716.	
	Millie D.	Ruth.	Nora.	Bess.		Millie D.	Ruth.	Nora.	Bess.
	Germs per cc. of milk.					Germs per cc. of milk.			
Mar. 24.....	940	1,640	1,790	2,410	Mar. 25.....	4,800	950	2,460	1,570
" 26.....	4,810	2,620	3,860	3,900	" 27.....	2,490	15,860	2,320	5,880
" 30.....	2,330	9,160	4,720	8,800	" 31.....	3,100	19,640	4,490	6,590
April 1.....	1,460	5,700	4,440	5,040	April 2......	15,400	5,810	3,870	4,030
" 3.....	3,190	7,850	1,220	4,610	" 4......	7,540	4,650	3,660	2,050
Average....	2,546	5,382	4,000	4,952		6,646	9,380	3,360	4,020
Gen. av.....	4,220					5,850			

While the average from each set of observations shows a distinct gain from handling the pail with the top on at all times it will be seen that this gain is largely due to the large counts obtained on two occasions when the top was off. This is really what is to be expected in a barn where the conditions producing dust in the air are fairly well avoided and it is only when the unexpected switching of the cow's tail while passing or the unintentional brushing against the side of the cow brings down its quota of dust and bacteria into the open pail that the increase in germ content is marked. However, since exactly these things are certain to happen occasionally it would seem the better practice, where it is the aim to produce a low germ content in the milk that the pails be handled as much as possible with the tops in place and especially when passing between or behind the cows.

Effect of disconnecting the milking parts.—Owing to the variation in the sizes of the teats on different cows it is often necessary to rearrange the teat cups when changing from one cow to another. This is a factor which did not enter into our previous tests since it was our practice before placing them in the brine after milking to arrange the teat cups in the order desired for the test at the succeeding milking. Since this factor would enter into the production of milk in a commercial way its influence was tested by handling the milking machine under most favorable conditions and exactly alike except that at certain milkings the teat cups were removed from the teat cup connectors and replaced just before the act of milking.

The effect of this change in the manner of operation is shown in Table XIII.

TABLE XIII.— EFFECT OF DISCONNECTING RUBBER PARTS AFTER REMOVING THEM FROM THE SALT SOLUTION.

1907.	Tubes not separated.				1908.	Tubes separated.			
	Machine No. 2437.		Machine No. 2716.			Machine No. 2437.		Machine No. 2716.	
	Millie D.	Ruth.	Nora.	Bess.		Millie D.	Ruth.	Nora.	Bess.
	Germs per cc. in milk.					Germs per cc. in milk.			
Dec. 30....	1,350	16,750	5,750	3,500	Jan. 2.....	11,100	5,060	6,280	3,780
Jan. 3.....	2,100	4,870	4,250	2,390	" 7.....	240	8,340	14,420	10,870
" a6.....	3,040	1,060	1,620	13,300	" 9.....	2,140	3,940	840	2,460
" 8.....	4,500	4,430	1,480	5,710	" 13.....	5,190	12,770	620	2,560
" 10.....	990	2,490	1,120	2,340	" 15.....	1,790	7,960	1,500	39,950
Average....	......	......	......	......	" 16.....	1,370	3,410	5,350	1,630
Average....	2,390	5,900	2,890	5,450		3,640	6,910	4,870	10,210
Gen. av.....	4,150					6,410			

These results show that while the average effect of this operation is only a slight increase of the germ content, this increase is produced by a marked rise on a few occasions. Apparently it is only occasionally that in the process of changing the teat cups foreign matter finds its way into milking tubes and thence into the milk. This is fortunate, since in milking a large dairy it is practically impossible to avoid an occasional change of teat cups.

CONCLUSIONS

The point which is emphasized by these studies is that the quality of milk obtained from a milking machine depends primarily upon the intelligent care which is exercised in the manipulation of the machine.

The most important item in this connection is the careful immersion of the milking parts in a brine or similar solution between milkings. This has been shown to be many times more efficacious than the most careful steaming. While there is

room for improvement in this particular, a 10 per ct. solution of common salt is fairly satisfactory for immersing the tubes.

The limit to which the germ content of the milk can be reduced turns largely upon the efficiency of the air filters and these have varied widely upon the different types of machines which have been studied.

Owing to the constantly shifting type of machine it has not been practicable to study the effect of seasonal variation upon the germ content of the milk. Such a study also is rendered difficult by the fact that there are important factors influencing the germ content of the machine-drawn milk which have not yet been determined. As a result, high numbers are occasionally obtained when there is no observed occasion for them. It will be necessary to get these factors fully under control before accurate work can be done in measuring the influence of the various factors.

One of the greatest difficulties in connection with this work has been to insure a proper degree of care in manipulating the machines and this difficulty will follow any attempt to produce milk with a low germ content on a commercial scale. The machines have now reached a degree of perfection where they can be reasonably expected to deliver milk of a germ content comparable with good hand milking when given proper attention.

THE BACTERIAL SOFT ROTS OF CERTAIN VEGETABLES. I:*

IN COOPERATION WITH VERMONT AGRICULTURAL EXPERIMENT STATION.

PART I. THE MUTUAL RELATIONSHIPS OF THE CASUAL ORGANISMS.

H. A. HARDING AND W. J. MORSE.†

SUMMARY.

1. This is part of an investigation of the soft rots of cabbage, cauliflower and turnip, conducted jointly by the Agricultural Experiment Stations of Vermont and New York, and deals with the morphology and cultural characters of 43 strains of organisms.

2. These strains have been found in connection with the soft rots of a considerable number of the common fleshy vegetables and some of them have been described in literature as separate species.

3. These strains appear to be identical in morphology and a cultural study upon more than 12,000 cultures did not indicate any constant cultural differences aside from the fermentation of sugars.

4. The results from 1,500 fermentation-tube tests indicate that the entire group attacks dextrose, lactose and saccharose with the formation of acid and growth in the closed arm but that the amount of gas normally formed is so close to the amount required to saturate the liquid in the fermentation tube that the appearance of gas in the closed arm is very irregular.

5. On account of this observed variation in gas formation the organisms are arranged in six groups each with its appropriate group number. So far as it has gone this study does not show that more than one species, in the customary meaning of the term, is represented in this collection of organisms but the final word in their classification should be deferred until after a study of the pathogenicity of these cultures.

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†During his studies of this problem Prof. Morse was Assistant Botanist of the Vermont Station; he is now Plant Pathologist of the Maine Station.

INTRODUCTION.

Almost every year the attention of plant pathologists is directed toward soft rots of some of the fleshy vegetables and in the aggregate the economic losses from this class of diseases are large. In a number of such diseases the casual organism has been isolated, studied and given a specific name. These rot-producing organisms are often closely related, so closely, in fact, that in working with a freshly isolated pathogen of this class one is usually in doubt as to whether the culture under consideration is a new species or a representative of a species already described.

The attention of one of us (H) was first directed to this group in 1897, in connection with an experimental study of the black rot of cabbage, at the University of Wisconsin. The soft rot of cabbage was observed[1] in the experimental fields and cultures made. When it was found that the organism present in the rotting tissue was distinct in its chromogenesis and other cultural characteristics from *Ps. campestris*, the germ causing the black rot of cabbage, the study of the soft-rot germ was not carried further. In 1898, while studying the distribution of *Ps. campestris* in Europe, a white liquefying organism was again encountered in connection with a soft rot of various members of the turnip family. Since 1899 study of this organism has been in association with Mr. F. C. Stewart, Botanist at the New York Agricultural Experiment Station.

In 1896, Mr. Stewart made successful inoculation experiments using germs isolated from diseased cabbage on Long Island and reproduced the soft rot as it appeared in the cabbage fields. In the following year he likewise determined experimentally that a destructive soft rot of *Amorphophallus simlense* could be reproduced under proper conditions by the inoculation of a pure culture of a species of bacterium which he had isolated from diseased plants of this species. No extended study of these casual organisms was conducted at this time. Since 1900 a comparative study of the bacteria causing

[1]Russell, H. L., and Harding, H. A. A bacterial rot of cabbage and allied plants. Wis. Agr. Exp. Sta. Bul. 65, p. 22. 1898.

the soft rots of cabbage and cauliflower has been conducted at the New York Agricultural Experiment Station. A preliminary report[2] of this work was read before Section G of the American Association for the Advancement of Science at Pittsburg, Pa., June 30, 1902, and printed in *Science,* August 22, 1902.

In 1898 Professor L. R. Jones of the University of Vermont isolated an organism which produced soft rot in carrots and other vegetables and later described this organism under the name of *Bacillus carotovorus.*[3] In the summer of 1899, being convinced that the soft rot of the cabbage was a disease closely allied to carrot rot, as to cause and attendant phenomena, he started a student assistant, Mr. F. R. Pember, on the study of the cabbage rot. Mr. Pember secured three organisms resembling *B. carotovorus* and like that capable of producing a soft rot of vegetables and made comparative studies of them. In 1901 the comparative study, at the University of Vermont, of the morphology and pathogenicity of this group of rot-producing organisms was assigned to one of us (M) and over a score of pathogenic cultures were isolated from various sources. Meanwhile Professor Jones was at work upon the question of the production and activities of the toxic substances and wall-dissolving enzyms which are elaborated by these bacteria.

The fact that these similar lines of investigation were being conducted at these adjoining Stations becoming known, a conference was held between the representatives of the two Stations in July, 1902, and the work of studying the soft rots of these vegetables was divided as follows: The determination of the mutual relationship of the germs involved was assigned to Messrs. Harding and Morse; the study of the enzyms elaborated and their relation to the host plants to

[2]Harding, H. A., and Stewart, F. C. A bacterial soft rot of certain cruciferous plants and *Amorphophallus simlense.* *Science*, N. S., **16**: 314–315. 1902.

[3]Jones, L. R. *Bacillus carotovorus*, n. sp., die Ursache einer weichen Fäulnis der Möhre. *Centbl. Bakt. u. Par., II,* **7**: 12–21; 61–68. 1901. Also, Jones, L. R. A soft rot of carrot and other vegetables. **Ann. Rep.** Vt. Agr. Exp. Station **13**: 299–332. 1901.

Prof. Jones; while the pathogenicity of the germs and the economic relations of the diseases were left to the activities of both Stations. Later, owing partly to the transfer of Mr. Morse to the Maine Station, it was decided that the work on the pathogenicity should be carried out at the New York Station. It was hoped that the three parts of this investigation might be published together, but this does not seem to be practicable. Accordingly, the present paper deals with the first two divisions, leaving the third to appear later.

The economic importance of this inquiry lies mainly in connection with the rots of carrots, cabbage, cauliflower and turnips. In order more fully to understand the relation of the organisms causing these rots it seemed desirable to include a study of a number of bacterial forms which have been known to cause similar diseases in other cultivated plants. Where these organisms are sufficiently similar to be able in turn to attack the above vegetables their importance in connection with any rotation of crops is evident.

It is a matter of regret, in view of the close relationship which has been found between pathogens on such a wide range of plants, that the circumstances did not permit a comparative study of all the germs known to cause soft rots of plants. It is evident that such a study would yield results of great value.

The earliest isolation of this class of organisms which has come to our attention was that by Professor Pammel in 1892. His attention had been called to a destructive rot of rutabagas and yellow turnips and he states that he "carefully removed with a sterilized scalpel some of the black areas adjoining healthy tissue with a platinum needle, using the test tube of agar. Several forms of bacteria were obtained, and one of these, a bacillus producing a whitish growth on the surface of the agar, when inoculated into an apparently healthy rutabaga produced rot."[4] These fields were undoubtedly like many which have since come under our observation in that there were two distinct diseases present at the same time.

[4]Pammel, L. H. Bacteriosis of rutabaga. (*Bacillus campestris*, n. sp.) Iowa Agr. College Exp. Station Bul. 27, p. 133. 1895.

Having later obtained well-marked results from inoculations with a yellow organism which he named *Bacillus campestris*, no further work was done with the white organism which, in the light of later experience, appears to have been the more important pathogen.

Strictly speaking, the black rot of cabbage and allied plants, caused by *Bacillus*, or as it is now called, *Pseudomonas campestris*, should be included among the soft rots. While this disease ordinarily manifests itself by a drying and browning of the foliage it also often appears as a soft rot of the fleshy tissue. However, as its casual organism can be easily distinguished from the germs producing the soft rots which we have been studying, we have not included *Ps. campestris* among the organisms discussed in this paper.

As has been already suggested, the prime object of our study was to remove the present confusion which exists as to the relationships of the closely allied, white organisms which cause the soft rots of the carrot, turnip, cabbage and cauliflower.

SOURCES OF OUR CULTURES.

Professor M. C. Potter presented the results of his study of a bacterial disease of turnips to the University of Durham Philosophical Society[5] in December, 1898, in which he named the casual organism *Pseudomonas destructans*, and presented a very similar paper at the British Association[6] meeting at Dover in September, 1899. The published abstracts of these papers characterized this disease as a white rot and included a brief description of *Pseudomonas destructans*. Aside from the pathogenicity, his description in these first papers is so brief that it is very doubtful if his organism could be recognized by its aid. He characterized the organism more fully in a paper read before the Royal Society[7] in December, 1900, and

[5]Potter, M. C. On a bacterial disease — white rot — of the turnip. From Univ. of Durham. Philo. Soc. Proc. Nov., 1899.

[6]Potter, M. C. On white rot — a bacterial disease — of the turnip. British Asso. for Adv. of Sci. Report for 1899: 921–922. 1900.

[7]Potter, M. C. On a bacterial disease of the turnip. (*Brassica Napus*). *Royal Soc. of London, Proc.* 67: 442–459, 1901. Reviewed also in *Ztschr. Pflanzenkr.*, 12: 170. 1902.

translated later into German.[8] Judging from correspondence with Prof. Potter, the casual organism had been lost before the autumn of 1902. In February, 1903, he kindly furnished us, for use in this comparative study, a culture which he had freshly isolated and believed to be *Pseudomonas destructans.* However, a flagella stain showed that this was a peritrichic organism and therefore would be classed, according to Migula, as a bacillus.

The organism which we received can hardly be looked upon as an accidental contamination since it is a typical member of the group producing soft rot in plants and is undoubtedly a true English representative of this widespread group. The failure of Prof. Potter to reisolate a Pseudomonas from decaying vegetables is not surprising in view of the fact that during the years in which we have been frequently making such isolations we have never isolated a white liquefying Pseudomonas producing this decay.

Later we obtained a culture labeled *Pseudomonas destructans* from Kral, but this was possibly derived from the same culture sent us under that name by Prof. Potter as it was likewise a bacillus.

In January, 1909, Professor Potter kindly furnished a third freshly isolated culture of *Pseudomonas destructans.* The arrangement of the flagella on this was also peritrichiate and consequently it should be classed as a bacillus. In this paper the culture furnished us by Prof. Potter in 1903 will be designated as Potter's Bacillus.

Reference has already been made to the publications by Professor Jones on the soft rots of carrot and other vegetables. These publications not only included an extended description of *Bacillus carotovorus,* but also gave the results of extensive tests of its pathogenicity when inoculated into a large number of common vegetables. These results showed that, under proper conditions, soft rots of a long list of common vegetables could be produced by inoculations from a pure culture of this germ. Fortunately the original type culture

[8] Potter, M. C. Ueber eine Bakterienkrankheit der Rüben (*Brassica Napus*). *Centbl. Bakt. u. Par., II,* 7: 282–288; 353–362. 1901.

of *Bacillus carotovorus* has been preserved by Professor Jones and was available for use in this comparative study.

Professor F. C. Harrison presented a paper at the Pittsburg meeting of the American Association for the Advancement of Science, entitled "A preliminary note on a new organism producing rot in cauliflower and allied plants,"[9] in which he briefly described the casual organism which he there named *Bacillus olcrcaceae.* In a later publication[10] he gave a very full account of the behavior of *Bacillus oleraceae* on different culture media as well as the results of inoculations of pure cultures of this bacillus into many of the common vegetables. As the result of such inoculations he reported soft rot being reproduced in cabbage, cauliflower, turnip, rutabaga, rape, radish, parsnip, carrot, mangel, sugar beet (slight), potato, celery, tomato (both ripe and green), artichoke (Jerusalem), asparagus, horse radish, rhubarb and onions. When we applied to Professor Harrison in 1902 for a culture of *Bacillus olereaceae* he was unable to furnish it because of the loss of all of his stock, but we were so fortunate as to obtain an authentic culture from one which he had previously furnished to Dr. Erwin F. Smith.

An interesting contribution to this subject was made in 1902 by Dr. A. Spieckermann[11] of the Agricultural Experiment Station at Münster, Germany. He isolated an organism which he found to be able to reproduce a soft rot in a considerable number of the common vegetables when inoculated into them in pure culture. The cultural characteristics of this organism differed in some particulars from the ones already described by Potter and Jones, being identical, as will be shown later, with the organism afterwards found and named by Townsend.[12] However, Spieckermann did not name

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[9]Harrison, F. C. Preliminary note on a new organism producing rot in cauliflower and allied plants. *Science*, N. S., **16**: 152. 1902.

[10]Harrison, F. C. A bacterial disease of cauliflower (*Brassica olereaceae*) and allied plants. Ontario Agr. College Bul. 137. 1904.

[11]Spieckermann, A. Beitrag zur Kenntniss der bakteriellen Wundfäulnis der Kulturpflanzen. Landw. Jahrb., **31**: 155–178. 1902.

[12]Townsend, C. O. A soft rot of the calla lily. U. S. Dept. of Agr., B. P. I., Bul. 60. 1904.

his organism, but in January, 1903, he kindly furnished us with a culture which will be referred to in this publication as Spieckermann's Bacillus.

On May 21, 1902, C. J. J. van Hall presented a doctorate thesis to the University of Amsterdam, entitled "Bijdragen tot de kennis der Bakterieele Plantenziekten,"[13] in which he included an extended description of an organism producing a soft rot in the Iris family and designated by him as *Bacillus omnivorus* n. sp. Dr. van Hall later published a discussion of the pathogenicity[14] of *Bacillus omnivorus* and its manner of attack upon the iris bulbs and plants. While the soft rot of the iris was outside of the group which we originally intended to study we obtained a culture of *Bacillus omnivorus* from Kral and included it among the organisms studied.

In 1904 Dr. C. O. Townsend[15] published a description of a soft rot of calla lily including that of the casual organism which he named *Bacillus aroideae.* Through the kindness of Dr. Townsend we were given a culture of this organism at the very beginning of our work and have made a comparative study of it in connection with the germs from the other sources.

In addition to these named cultures we have made a comparative study of 37 others, isolated from various vegetables. Pember A and C were obtained from decaying cabbages by Mr. F. R. Pember in 1899. In the summer and fall of 1901 one of us (M) isolated cultures XXV, XXVI, XXIX and XXXI from decaying early cabbages from the Vermont Experiment Farm garden; cultures XLVIII, XLIX, L, LI, LII, LIV, LV and LVI from a field of late cabbages in South Burlington, Vt., and cultures XCIV, XCV, XCVI, XCVIII, C, CI, CII, CIII from cabbages in a private storage house at Burlington, Vt. In 1903, an organism, designated as Tur-

[13] van Hall, C. J. J. Bijdragen tot de kennis der Bakterieele Plantenziekten. Doct. Thesis. Univ. of Amsterdam. 1902.

[14] van Hall, C. J. J. Das Faulen der jungen Schösslinge und Rhizome von *Iris florentina* und *Iris germanica*, verursacht durch *Bacillus omnivorus* v. Hall und durch einige andere Bakterienarten. *Ztschr. Pflanzenkr.*, **13**: 129–144. 1903.

[15] See footnote 12.

nip Rot D, was isolated at the Vermont Agricultural Experiment Station laboratory from decaying turnips growing on the same land from which were obtained the cabbage soft rot organisms XXV–XXXI two years previously.

At the New York Agricultural Experiment Station laboratory culture 0.2 e was isolated from a decaying cauliflower from Long Island in November, 1901. Culture 0.2 f was isolated in March, 1902, from a diseased cauliflower plant in the green house. Eleven days previous this cauliflower plant had been carefully inoculated with a pure culture of 0.2 e in order to test the pathogenicity of this culture and the reisolation was made to determine the fact that the disease which had been produced was actually caused by 0.2 e. The inoculation had been made as aseptically as possible and the point of inoculation covered with melted grafting wax. The material for the reisolation was taken from the advancing edge of the diseased area and the plates indicated the presence of a pure culture in the plant tissue.

In 1902 the cultures designated as Miller and Riverhead were isolated from decaying stalks of cabbage which had been planted commercially for the purpose of raising cabbage seed. The stalks were collected as typical examples of the early stages of the destructive rot which causes a heavy loss in the cabbage seed industry on Long Island practically every year and there were two stalks from each of two fields located about 10 miles apart in the eastern portion of the island.

Cultures labeled Miller Stalk 2 No. 1 and Miller Stalk 2 No. 2 were derived from the same diseased stalk while Miller Stalk 3 No. 1, Miller Stalk 3 No. 2 and Miller Stalk 3 No. 3 were likewise isolated at the same time from another similarly diseased cabbage stalk from the same field. Riverhead Stalk 2 No. 1 and Riverhead Stalk 3 No. 1 came from two cabbage stalks out of a second field.

Cultures 0.2 RBe and 0.2 RBi were isolated in November, 1901, from a rutabaga. This was obtained from a private garden near Phelps, N. Y., and the upper portion of the rutabaga was soft and vile smelling. The cultures were prepared from blackened fibro-vascular bundles passing through the

apparently sound tissue of the rutabaga. Both cultures were obtained from the same plant.

The cultures Cornell I, III and V were isolated in October, 1904, from two turnips from an experimental field at the Cornell Agricultural Experiment Station, cultures I and III being from the same turnip.

Thus this collection of cultures represents England, Holland, Germany, District of Columbia, Canada, Vermont and widely separated points in the State of New York. They were derived from turnip, iris, rape, calla lily, cauliflower and cabbage.

METHODS OF WORK.

On undertaking this comparative study in July, 1902, the first step was an exchange of cultures which had been isolated at the two Stations and a determination of their cultural characteristics. The media used in this study, with certain exceptions, were prepared in accordance with the suggestions of the report of September, 1897,[16] of the committee of the American Public Health Association on standard laboratory methods. The reaction of the media used at the New York laboratory was uniformly 1.5 per ct. normal acid to phenolphthalein while that used at the Vermont laboratory was the same during the earlier years of the study and later was made neutral to this indicator, as it was found that the organisms grew equally well, if not better, in a neutral medium. In the earlier work at the Vermont laboratory lean beef was used in preparing the media, but the resulting presence of muscle sugar in the broth led to the substitution of Liebig's meat extract. At the New York laboratory this meat extract was uniformly used except on rare occasions when beef was used as a check.

If these variations in the technique at the two laboratories had resulted in discordant results they would have been regrettable, but, as the results will show, such was not the case. On the other hand, the presence of these variations in the technique makes it all the more probable that the results here

[16]Report of the committee on standard methods for water analysis. *A. P. H. A. Proc.* (1897), **23**: 56–100. 1898.

given can be duplicated in any laboratory where care is given to approximating standard conditions of work.

One of the important items which should never be disregarded in comparative work of this kind is the vigor of culture. Especially when they have been long subjected to artificial conditions in a laboratory it is necessary to put the cultures through a revivifying process, a series consisting of transfers of young cultures through bouillon, gelatin and agar having been used with these germs. Comparative cultures were rarely made in duplicate but almost uniformly in triplicate. When cultures long in stock were tested without previously revivifying, discordant results from the three simultaneous cultures were occasionally obtained, while such comparisons made after the stock culture had been revivified practically always gave more accordant results.

In separating these cultures the main difference is in their ability to ferment the different sugars. Accordingly it was absolutely necessary for accurate results that the broth which was used as the basis of these tests should be free from muscle sugar. The absence of this sugar was determined by testing each lot of broth with *B. coli*, and when found to be present the sugar was destroyed by the growth of this organism. By using meat extract it was found possible to prepare bouillon free from this sugar, and all of the broth used at the New York laboratory was in this way made free of muscle sugar.

METHODS OF CLASSIFICATION.

Those familiar with such work will appreciate the difficulty encountered in comparing determinations upon so many organisms scattered over a term of years and made in different laboratories. It is rare that two sub-cultures from the same original will give identical quantitative and qualitative results on a variety of media when tested side by side and when considering the large number of cultures tested at different times and places the slight variations are bewildering. Some system of classification is absolutely essential to progress.

A large part of the work and delay in connection with this study was due to the absence of such a well-elaborated system.

The suggestion of Fuller & Johnson[17] that the most stable reactions of bacteria could be printed on a card and the reactions of the culture being studied could be indicated by + or —, as the facts required, was a step in the right direction. As soon as there was a collection of these cards the difficulty of their arrangement became evident and this was met in an ingenious way by Gage and Phelps.[18] They devised a group number which both recorded the more important culture reactions and provided a basis for an orderly arrangement of the cards. The value of these improvements was so evident that on this basis a committee of the Society of American Bacteriologists has worked out an official classification card. While this card is probably not in its finished form it has such marked advantages over any other method of classification which is now available that it has been utilized in presenting the results of the present study.

The Society card consists of three essential parts: (1) A group number (see page 108) along the lines originally suggested by Gage, which records the more important facts regarding an organism and at the same time provides a means of arranging the records so that duplicates can be found readily; (2) A brief characterization (see page 110) which may be filled in by means of + or —, as suggested by Fuller and Johnson, and which serves as a means of further comparing germs with the same group number; and (3) A provision for tersely recording the detailed features of cultures upon the common media as first outlined by Chester[19] (see page 130).

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[17] Fuller, G. W., and Johnson, Geo. A. On the differentiation and classification of water bacteria. *Jour. Exp. Med.*, **4**: 609–626. 1899. Similar article in *A. P. H. A., Proc.* **25**: 580–586. 1899.

[18] Gage, S. De M., and Phelps, E. B. On the classification and identification of bacteria with a description of the card system in use at the Lawrence Experiment Station for records of species. *A. P. H. A., Proc.* **28**: 494–505. 1903.

[19] Chester, F. D. A manual of determinative bacteriology. New York: MacMillan. 1901.

The basis upon which the group number is computed according to the Society card of 1907, is given in Table I.

TABLE I.

A NUMERICAL SYSTEM OF RECORDING THE SALIENT CHARACTERS OF AN ORGANISM. (GROUP NUMBER.)

100.	Endospores produced
200.	Endospores not produced
10.	Aerobic (Strict)
20.	Facultative anaerobic
30.	Anaerobic (Strict)
1.	Gelatin liquefied
2.	Gelatin not liquefied
0.1	Acid and gas from dextrose
0.2	Acid without gas from dextrose
0.3	No acid from dextrose
0.4	No growth with dextrose
01	Acid and gas from lactose
.02	Acid without gas from lactose
.03	No acid from lactose
.04	No growth with lactose
.001	Acid and gas from saccharose
.002	Acid without gas from saccharose
.003	No acid from saccharose
.004	No growth with saccharose
.0001	Nitrates reduced with evolution of gas
.0002	Nitrates not reduced
.0003	Nitrates reduced without gas formation
.00001	Fluorescent
.00002	Violet chromogens
.00003	Blue "
.00004	Green "
.00005	Yellow "
.00006	Orange "
.00007	Red "
.00008	Brown "
.00009	Pink "
.00000	Non-chromogenic
.000001	Diastasic action on potato starch, strong
.000002	Diastasic action on potato starch, feeble
.000003	Diastasic action on potato starch, absent
.0000001	Acid and gas from glycerine
.0000002	Acid without gas from glycerine
.0000003	No acid from glycerine
.0000004	No growth with glycerine

The genus, according to the system of Migula, is given its proper symbol, which precedes the number, thus:

BACILLUS COLI (Esch.) Mig.	becomes	B.	222.111102
BACTERIUM SUICIDA Mig.	"	Bact.	222.232203
PSEUDOMONAS CAMPESTRIS (Pam.) Sm.	"	Ps.	211.333251
BACILLUS ALCALIGENES Petr.	"	B.	212.333102

RESULTS OF OUR STUDY.

The results of our attempts to classify these cultures representing four named species and thirty-nine other cultures isolated from diseased vegetables are given in Table II.

TABLE II.— SHOWING THE GROUP NUMBER AND OTHER CLASIFICATORY FEATURES OF THE GERMS STUDIED.

Group Number.	NAME.	Morphology							Cultural Features.																		Biochem. Features.													
									Broth.			Agar.				Gel. Plate.					Gel. Stab.		Potato.							Liquefaction			Milk.						
		Diameter over *mu*.	Chains.	Endospores.	Capsule.	Pseudozoogloea.	Motile.	Gram's stain.	Turbid.	Pellicle.	Sediment.	Shining.	Dull.	Wrinkled.	Chromogenic.	Round.	Proteus-like.	Rhizoid.	Filamentous.	Curled.	Surface growth.	Needle growth.	Moderate.	Abundant.	Discolored.	Starch destroyed.	Grows at 37 C.	Grows in Cohn's Sol.	Grows in Uschinsky's Sol.	Gelatin.	Casein.	Agar.	Acid curd.	Rennet curd.	Casein peptonized.	Indol.	Nitrates reduced.	Fluorescent.	Plant pathogen.
B.221.1113022	Bacillus carotovorus	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" oleraceae	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" omnivorus	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XXV	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XXVI	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XXIX	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XXXI	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" L					+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" LI					+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" LII					+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" LV					+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XCIV	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XCV	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XCVI					+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" XCVIII	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" CI	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" CII	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" CIII	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" Pember A	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" Pember C	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	" O. R. B e	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+

B.221.1113022	"	O. R B i	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	O. 2 f	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Cornell I	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Cornell III	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Cornell V	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Miller 2 No. 1	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Miller 2 No. 2	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Miller 3 No. 2	−	+	−	−	+	+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Miller 3 No. 3	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Riverhead 2 No. 1	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	LVI	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1113022	"	Miller 3 No. 1	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1123022	"	XLVIII	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.1213022	"	C	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2113022	"	O. 2 e	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2113022	"	LIV	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2123022	"	Potter's	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2123022	"	Riverhead 3 No. 1	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2223022	"	XLIX	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2223022	"	Turnip Rot D	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2223022	"	Spieckermann's	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+	−	+	+	+	−	+
B.221.2223022	"	aroideae	−	+	−	−		+	−	+	+	+	+	−	−	−	+	−	−	−	−	+	+	+	+	−	+	+	−	+	+	+	−	+		+	+	+	−	+

The above table presents as concisely as possible the results of observations made under 38 headings. These observations were made upon an average of 25 cultures for each of the 43 germs which were studied, or an average of approximately 1,000 cultures for each heading. Owing to the fact that a single culture would furnish the information given under a number of headings, only about 12,000 cultures are actually represented in this table, although some thousand additional were required in the preliminary cultivations and in the revivifying process.

While the above results are perfectly accordant in all of the items covered by + and — it would be misleading to assume that no apparently discordant observations were made. Every item was determined a number of times, usually in triplicate, and in practically all cases these determinations were made in both laboratories, the more important of them having been determined independently by four different workers.

The importance of revivified cultures has already been emphasized and it was in the determinations which were made previous to the application of this preliminary cultivation that the larger part of the variation was encountered. However, revivication does not remove all of the tendency to vary which is resident in some of the cultures.

In summarizing in the table the results which were not entirely accordant the rule has been followed that a single well-marked positive result was more important than a number of negative ones. Wherever a single positive result was marked as doubtful for any reason and the other observations were uniformly negative the test has been recorded as negative in the table, but attention will be called to such cases in the following remarks.

Pellicle on broth. The pellicle on broth is usually thin and in many of the earlier observations it was recorded as absent. Careful observations on cultures which had not been disturbed showed that the pellicle begins with the formation of floating masses of pseudozooglea which are gradually united into a delicate film. If the culture is even gently shaken these sink

and the pellicle which would have resulted is destroyed and may not be reformed.

While this delicate pellicle may be taken as characteristic for the entire collection of cultures, six members of the B. 221.1113022 group—*B. oleraceae,* CI, 0.2 f, Miller Stalk 3 No. 3, Riverhead Stalk 2 No. 1 and Miller Stalk 3 No. 1—have from time to time shown a pellicle somewhat stronger than the rest, which tends to hold together when shaken. The reasons for this variation have not been more closely determined.

Agar colonics. Townsend in his description of *B. aroideae*[20] laid some stress on the diagnostic value of radiating surface colonies which appeared on lightly seeded agar plates that had been inoculated from fresh cultures and been held at 22° to 35° C. Early in the work some attention was given to this point, particularly at the Vermont laboratory. It was found that on lightly seeded plates these radiating amoeboid-shaped colonies were usually produced by *B. aroideae,* Spieckermann's Bacillus and Turnip Rot D, lending color to the idea that the absence of gas formation was in some manner correlated with a tendency to the formation of these colonies. However, the formation of these colonies was not restricted to these organisms and on at least one occasion they were formed by 0.2 f, Vermont XLVIII and Turnip Rot D when they were not formed by *B. aroideae* nor Spieckermann's Bacillus, although all five were tested together under parallel conditions of media, temperature and dilution.

At the New York laboratory no systematic study was made of this point partly because the work at the Vermont laboratory indicated that it had no diagnostic value and largely because variations in moisture and temperature effect such marked changes in the colony growth of practically all bacteria. The occasional formation of radiating colonies was observed in connection with a considerable number of the

[20]Townsend, C. O. A soft rot of the calla lily. U. S. Dept. of Agr. B. P. I., Bul. 60, pp. 17 and 39. 1904.

forms, but no determination was made of the exact conditions under which they were produced.

Potato discolored. The difficulty with this determination lay not so much in a variation in the cultures as in the different conceptions which various workers had of the meaning of the term. As used in the table it refers to the formation of the nearly white halo which is seen around the margin of the growth with certain species of bacteria. This was not observed with this collection of cultures. On the contrary, the portion of the potato not covered with the luxuriant glistening, creamy growth was ordinarily darkened to a faint brownish gray, the extent of this change varying apparently with the characteristics of the potato itself.

Potato starch destroyed. This item has been added to the classification card recently and the determinations were made at the New York laboratory only. The test was made on sterilized potato cylinders in test tubes upon which cultures were grown for two weeks. These potato cultures were crushed in porcelain mortars and 50 cc. of water added to separate the particles so that the effect of the iodine could be easily seen. The presence of unchanged starch was determined by the gradual addition of a weak solution of iodine in potassium iodide. After a sufficient amount has been added to satisfy some of the other compounds which are present the starch grains are turned to a blue-black. The extent of the reduction of the starch by the bacterial growth is estimated on the basis of similar tests of uninoculated potato cylinders. In none of these cultures was the starch reduction complete, but amylodextrin was formed. (See page 174.) This change was expressed by 2 in the appropriate place in the group number.

For the details of this method of determining this action on the starch, we are indebted to Dr. Erwin F. Smith who assisted us by correspondence and by a demonstration in connection with the meeting of the Society of American Bacteriologists at Baltimore.

Uschinsky's Solution. The advantage of this solution lies in the definite chemical compounds used in its preparation

but unfortunately the variation in the results obtained from its use is wider than in a majority of the media ordinarily employed. Jones and Townsend found this medium well suited to the forms which they studied earlier, but the use of this medium in the later study at the Vermont laboratory did not result in any visible growth. A test of the entire collection of cultures at the New York laboratory in 1909 likewise failed to produce growth in any case. A study of the commercially pure chemicals which had been obtained from one of the most responsible houses revealed the fact that the compound supposed to be di-basic potassium phosphate was really the mono-basic salt. This produced a marked acidity in the medium and probably inhibited the growth. A redetermination with chemicals which were true to name gave an abundant growth in all cases.

Gelatin liquefaction. All of the cultures in this collection produced an evident liquefaction in gelatin stab in all of the many tests except in the case of one series of cultures made at the New York laboratory in 1905, when the entire collection either liquefied very slowly or entirely failed to do so. Shortly before this date some attention was being given in Europe to the suggestion of van't Hoff[21] of the addition of formalin to gelatin to raise its melting point. The gelatin used in the above tests was of the "Gold Label" quality and had been imported through the regular channels. A discussion of this difficulty in the matter of liquefaction before the Society of American Bacteriologists at their Philadelphia meeting brought out the fact that a number of other workers had had similar experiences. With the substitution of a new supply of gelatin all of the soft-rot cultures again produced liquefaction.

While all of these cultures produced an evident liquefaction of gelatin the rate at which this result was produced varied widely both among the different cultures tested at the same time and among the different tests of a single culture. The cultures known as Cornell I and Cornell V were isolated on

[21] van't Hoff, H. J. Erhöhung des Schmelzpunktes der Nährgelatin mittels Formalin. *Centbl. Bakt. u. Par., I,* **30**: 368. 1901.

practically the same date from diseased turnips in the same field and the qualitative record of these cultures in the above table is identical in all particulars. They were as similar as two subcultures from a single source would be expected to be except in the matter of liquefaction. In parallel cultures made in triplicate at the same time, on gelatin stabs from the same flask of gelatin, from agar slopes treated as nearly alike as possible Cornell I produced large dry pits while Cornell V liquefied practically the entire stabs in three weeks. Again in his description of *B. aroideae,* Townsend called attention to the rapidity of its action, completing the liquefaction in 3—5 days. In our studies the culture which he furnished us varied relatively from one of the more rapid to one of the slowest in the collection. The rate and form of liquefaction appears to vary with what may be termed the general vigor of the culture and more especially with regard to the relation of the culture to oxygen. Unfortunately our knowledge of the factors which influence the cultures in these particulars is extremely fragmentary.

Milk—Acid Curd. The distinction between acid and rennet curds is of historical rather than practical value in the study of many bacterial forms. In this group the distinction cannot be made with certainty and different observers have varied accordingly. The formation of the curd is probably due to the joint action of an enzym and of acid. The record was made of acid curd + because there is an evident acid formation preceding the curdling.

Casein peptonized. Here again the various observers differed markedly in their conclusions because the visible digestion of the curd is so slight that it cannot with certainty be differentiated from the shrinking which would result from the action of the acid on the curd. The action of the various cultures on milk was alike and the final record of + was based on the results of milk agar plates prepared after the suggestion of Hastings[22] where the ability of the organisms to attack the casein seems to be clearly brought out.

[22]Hastings, E. G. Milchagar als Medium zur Demonstration der Erzeugung proteolytischer Enzyme. *Centbl. Bakt. u. Par., II,* **10**: 384. 1902.

Indol. The production of indol by this collection of cultures is slight in all cases and the various observers have not always considered that the red color produced by the test was sufficient to be considered positive. However in both laboratories series of tests have been considered as sufficiently decided to be classed as positive. It will be noted that this result is not in accord with the record of Townsend[23] with *B. aroideae*, but the disagreement is undoubtedly a matter of interpretation of results rather than a difference in organisms.

Nitrate reduction. It was only in a few instances that the reduction of nitrates was not detected in the standard solutions. In all of these instances succeeding cultures showed the characteristic color reaction. The cultures which failed had not been revivified previous to the test.

Gas formation. As has already been indicated the gas formation from dextrose, lactose and saccharose in the fermentation tube offers a basis for classifying this collection of cultures. Owing to the importance of the observation on this point and to the somewhat conflicting results obtained with some of the cultures, the results of the various determinations are here given in Table III.

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[23] Townsend, C. O. loc. cit. p. 32.

TABLE III.— BEHAVIOR OF SOFT ROT BACTERIA IN FERMENTATION TUBES.

Date	Laboratory.	Observer.	Germ.	Group No.	Revivified.	Dextrose. Gas.	Dextrose. Per ct.	Lactose. Gas.	Lactose. Per ct.	Saccharose. Gas.	Saccharose. Per ct.
1903	....	....	B. omnivorus	....	....	....	....	....	....	....	....
1903	N	P	"	.111	—	+	....	+	....	+	....
1903	V	M	"	.111	—	+	8	+	15	+	6
1904	V	M	"	.1	+	+	2	....	....	....	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.1	+	+	15	....	....	....	....
1903	....	....	XXV	....	....	....	....	....	....	....	....
1903	N	P	"	.111	—	+	....	+	....	+	....
1903	V	M	"	.111	—	+	8	+	7	+	3
1903	V	S	"	.111	—	+	5	+	12	±	10
1903	V	P	"	.1	—	....	....	....	....	+	6
1904	V	M	"	.1	+	+	....	....	....	....	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.1	+	+	10	....	....	....	....
1905	V	S	"	.1	+	+	....	....	....	....	....
1903	N	P	XXVI	.111	—	+	....	+	....	+	....
1903	V	M	"	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	N	P	XXIX	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	N	P	XXXI	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	+	12	+	18	+	8
1903	N	P	L	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	N	P	LI	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	N	P	LII	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	N	P	LV	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	N	P	XCVI	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1903	V	M	Pember C	.111	—	+	18	+	7	+	30
1903	V	S	"	.1	—	....	....	±	8	....	....
1903	V	S	"	.111	—	+	13	±	2	+	14
1903	N	P	"	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1904	V	M	"	.1	+	+	20	....	....	....	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	N	P	Cornell I	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	+	5	+	12	+	5
1905	N	P	Cornell III	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	+	....	+	15	+	4
1905	N	P	Cornell V	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	+	5	+	15	+	5
1903	N	P	Miller 2 No. 1	.111	—	+	....	+	....	+	....
1904	N	P	"	.111	—	+	....	+	....	+	....

TABLE III.— FERMENTATION TUBES —(*Continued*).

Date	Laboratory.	Observer.	Germ.	Group No.	Revivified.	Dextrose.		Lactose.		Saccharose.	
						Gas.	*Per ct.*	Gas.	*Per ct.*	Gas.	*Per ct.*
1903	N	P	Miller 2 No. 2	.111	—	+	....	+	....	+	....
1904	N	P	“	.111	—	+	....	+	....	+	....
1904	V	M	“	.2	+	—	....	....	....	....	....
1905	V	S	“	.111	+	+	10	+	10	+	10
1905	N	P	“	.111	+	+	....	+	....	+	....
1902	V	M	B. carotovorus	.111	—	+	....	+	....	+	....
1903	N	P	“	.111	—	+	....	+	....	+	....
1903	V	M	“	.111	—	+	....	+	....	+	....
1903	V	M	“	. 11	—	....	....	+	....	+	....
1904	N	P	“	.212	—	—	....	+	....	—	....
1905	N	P	“	.111	+	+	....	+	....	+	....
1905	V	S	“	.1	+	+	....	....	....	....	....
1903	N	P	B. olereaceae	.112	—	+	....	+	....	—	....
1903	V	M	“	.111	—	+	4	+	10	+	3
1904	N	P	“	.112	—	+	....	+	....	—	....
1904	N	H	“	.211	—	—	....	+	....	+	....
1904	V	M	“	.1	+	±	1	....	....	....	....
1905	V	S	“	.1	+	+	10	....	....	....	....
1905	N	P	“	.111	+	+	....	+	....	+	....
1904	V	M	O. RBe	.2	—	—	....	....	....	....	....
1905	V	M	“	.1	—	±	5	....	....	....	....
1905	V	S	“	.111	+	±	1	+	5	+	....
1905	N	P	“	.111	+	+	....	+	....	+	....
1903	N	P	O. RBi	.111	—	+	....	+	....	+	....
1904	N	P	“	.111	—	+	....	+	....	+	....
1904	V	M	“	.2	+	—	....	....	....	....	....
1905	V	S	“	.111	+	+	10	+	12	+	5
1905	N	P	“	.111	+	+	....	+	....	+	....
1903	N	P	Riverhead 2 No. 1	.111	—	+	....	+	....	+	....
1904	N	P	“	.111	—	+	....	+	....	+	....
1904	N	H	“	.211	—	—	....	+	....	+	....
1904	V	M	“	.2	+	—	....	....	....	....	....
1905	V	S	“	.111	+	+	8	+	12	+	10
1905	N	P	“	.111	+	+	....	+	....	+	....
1903	N	P	CI	.111	—	+	....	+	....	+	....
1904	N	P	“	.1	+	±	1	....	....	....	....
1904	N	P	“	.111	—	+	....	+	....	+	....
1905	N	P	“	.111	+	+	....	+	....	+	....
1905	V	S	“	.1	+	±	10	....	....	....	....
1905	V	S	“	.112	+	±	1	+	12	—	....
1903	N	P	XCV	.111	—	+	....	+	....	+	....
1903	N	P	“	.212	—	—	....	+	8	—	....
1904	N	P	“	.111	—	+	....	+	....	+	....
1902	V	M	Pember A	.111	—	+	4	+	8	+	10
1903	V	M	“	.111	—	+	10	+	10	+	16
1903	N	P	“	.112	—	+	....	+	....	—	....
1903	V	M	“	. 1	—	....	....	....	....	±	8
1903	V	S	“	.1	—	±	3	....	....	....	....
1903	V	S	“	.111	—	±	6	+	10	±	4
1904	N	P	“	.112	—	+	....	+	....	—	....
1905	N	P	“	.111	+	+	....	+	....	+	....
1905	V	S	“	.1	+	+	18	....	....	....	....
1903	N	P	LVI	.112	—	+	....	+	....	—	....
1904	N	P	“	.121	—	+	....	—	....	+	....
1902	N	P	0.2 f	.21	—	—	....	+	10	....	....
1904	N	P	“	.111	—	+	....	+	....	+	....
1904	N	P	“	.211	—	—	....	+	....	+	....
1904	V	M	“	.2	+	—	....	....	....	....	....

TABLE III.— FERMENTATION TUBES —(*Continued*).

Date	Laboratory.	Observer.	Germ.	Group No.	Revivified.	Dextrose.		Lactose.		Saccharose.	
						Gas	*Per ct.*	Gas	*Per ct.*	Gas	*Per ct.*
1905	V	S	0.2 f.	.111	±	+	10	+	10	+	5
1905	N	P	"	.111	+	+	....	+	....	+	....
1906	N	P	"	.1	+	±	....	....	....	....	....
1906	N	P	"	.222	+	—	....	—	....	—	....
1903	N	P	CII.	.222	—	—	....	—	....	—	....
1904	N	P	"	.222	—	—	....	—	....	—	....
1904	V	M	"	.1	—	+	1	....	....	....	....
1905	V	S	"	.1	+	+	10	....	....	....	....
1905	V	S	"	.111	+	±	1	+	12	+	4
1905	N	P	"	.111	+	+	....	+	....	+	....
1903	N	P	CIII.	.212	—	—	....	+	....	—	....
1903	V	M	"	.212	—	—	....	+	8	—	....
1903	V	M	"	.1	—	....	....	+	5	....	....
1904	V	M	"	.1	+	+	1	....	....	....	....
1904	N	P	"	.212	—	—	....	+	....	—	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.111	+	±	1	+	12	±	.5
1903	N	P	XCVIII.	.111	—	+	....	+	....	+	....
1903	V	M	"	.222	—	—	....	—	....	—	....
1903	V	S	"	.212	—	—	....	±	8	—	....
1903	V	S	"	.1	—	....	....	+	5	....	....
1904	V	M	"	.1	+	+	1	....	....	....	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	+	10	+	10	+	5
1903	N	P	XCIV	.211	—	—	....	+	....	+	....
1903	V	M	"	.222	—	—	....	—	....	—	....
1903	V	S	"	.212	—	—	....	+	8	—	....
1903	V	S	"	.1	—	....	....	+	8	....	....
1904	V	M	"	.1	+	+	1	....	....	....	....
1904	N	P	"	.111	—	+	....	+	....	+	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	+	8	+	10	+	5
1903	N	P	Miller 3 No. 3.	.222	—	—	....	—	....	—	....
1904	N	P	"	.222	—	—	....	—	....	—	....
1904	V	M	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.111	+	+	1	+	8	+	1
1905	N	P	"	.111	+	+	....	+	....	+	....
1903	N	P	Miller 3 No. 2.	.222	—	—	....	—	....	—	....
1903	V	M	"	.212	—	—	....	+	5	—	....
1904	V	M	"	.2	+	—	....	....	....	....	....
1904	N	P	"	.222	—	—	....	—	....	—	....
1905	N	P	"	.111	+	+	....	+	....	+	....
1905	V	S	"	.111	+	±	5	+	4	+	1
1905	V	S	"	.2	+	—	....	....	....	....	....
1903	N	P	Miller 3 No. 1.	.222	—	—	....	—	....	—	....
1904	N	P	"	.222	—	—	....	—	....	—	....
1904	V	M	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.1	+	±	1	....	....	....	....
1905	V	S	"	.112	+	±	1	+	5	—	....
1905	N	P	"	.211	+	—	....	+	....	+	....
1905	N	P	"	.2	+	—	....	....	....	....	....
1906	N	P	"	.22	+	—	....	—	....	....	....
1906	N	P	"	.111	+	+	....	±	....	±	....
1902	V	M	XLVIII.	.212	—	—	....	+	8	—	....
1903	N	P	"	.112	—	+	....	+	....	—	....
1903	V	M	"	.222	—	—	....	—	....	—	....
1903	V	M	"	.1	—	....	....	+	2	....	....
1903	V	M	"	.212	—	—	....	+	9	—	....
1904	V	M	"	.2	+	—	....	....	....	....	....

TABLE III.— FERMENTATION TUBES —(*Concluded*).

Date	Labor-atory.	Obser-ver.	Germ.	Group No.	Reviv ified.	Dex-trose.		Lactose.		Saccha-rose.	
						Gas	*Per ct.*	Gas	*Per ct.*	Gas	*Per ct.*
1904	N	P	XLVIII, cont'd...	..112	—	+	....	+	....	—	....
1905	N	P	" ...	.212	+	—	....	+	....	—	....
1905	V	S	" ...	.2	+	—	....	....	....	....	....
1905	V	S	" ...	.112	+	±	1	+	12	—	....
1905	N	P	" ...	.2	+	—	....	....	....	....	....
1906	N	P	" ...	.21	+	—	....	+	....	....	....
1906	N	P	" ...	.212	+	—	....	±	....	—	....
1903	N	P	C..............	.121	—	+	....	—	....	+	....
1904	N	P	"...............	.121	—	+	....	—	....	+	....
1903	N	P	LIV............	.211	—	—	....	+	....	+	....
1904	N	P	"	.211	—	—	....	+	....	+	....
1902	N	H	0.2 e...........	.21	—	—	....	+	10	....	....
1903	V	M	"	.212	—	—	....	±	1	—	....
1903	V	M	"	.211	—	—	....	+	6	+	4
1904	V	M	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.211	+	—	....	+	10	±	2
1905	N	P	"	.211	+	—	....	+	....	+	....
1905	N	P	"	.2	+	—	....	....	....	....	....
1906	N	P	"	.11	+	±	....	+	....	....	....
1906	N	P	"	.1	+	±	....	....	....	....	....
1906	N	P	"	.211	+	—	....	+	....	±	....
1903	V	M	Potter's Bacillus...	.212	—	—	....	+	4	—	....
1904	V	M	" ...	.2	+	—	....	....	....	....	....
1905	V	S	" ...	.2	+	—	....	....	....	....	....
1905	V	S	" ...	.21	+	—	....	+	10	....	....
1905	N	P	" ...	.212	+	—	....	+	....	—	....
1905	N	P	" ...	.2	+	—	....	....	....	....	....
1906	N	P	" ...	.21	+	—	....	+	....	....	....
1906	N	P	" ...	.212	+	—	....	±	....	—	....
1903	N	P	Riverhead 3 No. 1.	.212	—	—	....	+	....	—	....
1904	N	P	" .	.212	—	—	....	+	....	—	....
1904	N	H	" .	.222	+	—	....	—	....	—	....
1904	V	M	" .	.2	+	—	....	....	....	....	....
1905	V	S	" .	.2	+	—	....	....	....	....	....
1905	V	S	" .	.222	+	—	....	—	....	—	....
1905	N	P	" .	.222	+	—	....	—	....	—	....
1903	V	S	B. aroideae.......	.222	—	—	....	—	....	—	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	N	P	"	.222	+	—	....	—	....	—	....
1905	N	P	"	.2	+	—	....	....	....	....	....
1906	N	P	"	.22	+	—	....	—	....	....	....
1903	V	S	Spieckermann Bac.	.222	—	—	....	—	....	—	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	N	P	"	.222	+	—	....	—	....	—	....
1905	N	P	"	.2	+	—	....	....	....	....	....
1903	N	P	XLIX...........	.222	—	—	....	—	....	—	....
1904	N	P	"	.222	—	—	....	—	....	—	....
1903	N	P	Turnip Rot D .	.222	—	—	....	—	....	—	....
1903	V	S	"	.222	—	—	....	—	....	—	....
1904	V	M	"	.2	+	—	....	....	....	....	....
1904	N	P	"	.222	—	—	....	—	....	—	....
1904	N	H	"	.222	+	—	....	—	....	—	....
1905	N	P	"	.222	+	—	....	—	....	—	....
1905	V	S	"	.2	+	—	....	....	....	....	....
1905	V	S	"	.2	+	—	....	....	....	....	....

It will be seen from this table that the determinations of fermentative ability extended from 1902 to 1906, but that the larger amount of work on this phase of the subject was done in 1904 and 1905. Under laboratories, V and N refer to the Vermont and New York laboratories respectively. Under observers, M and H refer to the authors while S and P indicate that the actual manipulations of the determinations were done by L. P. Sprague or M. J. Prucha, assistants at the two laboratories. These tests were made under the immediate supervision of the authors, and the results were, for the most part, personally inspected by them, and they accept the responsibility for their accuracy.

Under group number is given the group number which would result from the particular determinations in question and an inspection of this heading under each organism brings out sharply the variations observed.

It should be remembered that each of the 550 determinations of fermentative ability recorded in the above table was conducted almost exclusively in triplicate, a comparatively small number having been made in duplicate so that this table really summarizes the results from approximately 1,500 fermentation tube cultures. It occasionally happens that in a fermentation test in triplicate, gas will not appear in one or more of the tubes and this is especially liable to happen where the total amount of gas is small, as in the case of this group of organisms. A complete record of these discordant results was kept at the Vermont laboratory and the cases are indicated in the table by ±. The total number of these cases observed at the Vermont laboratory was 23. At the New York laboratory where the card system of note keeping was being tried in various forms the record on the card was made on the basis of the triplicate test rather than that of the individual fermentation tube and the exact number of these variations is not known, but they were probably not greater than those given for the Vermont laboratory.

In the fermentation tubes which were used the closed arm has a capacity of 10 cc. In all but a few cases the gas produced had a volume of 1 cc. or less and accordingly was re-

corded as 10 per ct. or less. Owing to the rounded form of the upper end of the fermentation tube it is difficult to estimate quantities under 10 per ct. with any considerable accuracy. Since practically all of the determinations were under this amount an accurate measurement was not attempted at the New York laboratory, but fortunately this was practically always done at the Vermont laboratory and the resulting measurements are given in the table.

A striking fact brought out by this table is the frequent failure to form gas which occurred in fermentation tests made with the same organism at different times. So marked was this tendency to vary that contradictory results were obtained with 21 of the 43 strains which were studied. This number would undoubtedly have been even larger if all of the strains had received an equal amount of study. Those with which the action on each of the sugars was tested on but two occasions make up 13 of the 22 strains among which variations were not noted. Taking the results as they stand there were 91 out of a total of 550 tests which did not show gas where it was found at other tests. Accordingly, when making a fermentation test in triplicate with one of these cultures the chances were over 16 per ct. that the conclusion reached was diametrically opposed to the truth, provided we accept the contention that a positive result is of more value than a negative result in fermentation test, proper care being used to prevent outside contamination and to provide uniform conditions. If this chance of error is considered as restricted to the strains with which variation was actually observed the above record does not express the actual gas-forming ability of the organism in 91 out of 347 observations, or 26 per ct.

The influence of the revivifying process on the certainty of a correct result is shown by comparing the error noted when this preliminary treatment was given with the error when it was omitted. Where the cultures had not been previously revivified, but inoculations were made into the fermentation tubes from young, actively-growing agar slopes, there was an error in 63 out of 189 observations, or 33 per ct. Where the cultures were given a preliminary cultivation as already ex-

plained (page 106), there were 28 errors out of 158 trials, or 18 per ct. This decrease of 15 per ct., or practically one-half, in the inaccuracy of the test brings out clearly the importance of revivifying cultures before attempting to determine their fermentative ability.

Again it will be noted that the failure to form gas during a part of the tests is not equally distributed among the three sugars, but that there are 47 cases with dextrose, 17 with lactose and 27 with saccharose. While it is true that a few more tests were made with dextrose than with either of the other sugars, this increase is not at all proportional to the larger number of failures.

In arranging Table III the organisms which had always formed gas from all of the sugars at all of the trials were placed first, followed by those in which failures to form gas had been noted. These latter were arranged in the order of the frequency of this failure down to Miller Stalk 3 No. 1 which, while it formed gas from each of the sugars during some of the tests, failed to do so in 13 out of 21 instances.

The fermentative vigor of these cultures was fairly proportional to this arrangement. The fairly distinct amounts of gas formed by the first cultures in the table gradually diminishes down the table until there is rarely more than a small bubble with dextrose in the case of CII, CIII, XCVIII, XCIV and Miller Stalk 3 Nos. 1, 2 and 3. The amounts of gas formed from saccharose also undergoes a like shading down, but its formation in appreciable quantities continues beyond the point where the formation of gas from dextrose ceases. Beginning with Potter's Bacillus there is a group which does not form visible gas from either dextrose or saccharose, but is able to form it from lactose. The remaining cultures in this table have never produced visible gas in the fermentation tubes in any of the determinations which have been made.

Riverhead Stalk 3 No. 1 is a significant member of the group connecting this last group with the one preceding it since in the earlier studies of this organism it fermented

lactose with evident gas formation, but in all of the later studies it failed to produce gas even after having been revivified. Although this germ apparently lost its ability to produce gas after the beginning of this study it should not be concluded that this was the rule, as it was really an exception. Owing to the stimulating effects of revivification which was practiced only during the latter part of the study a very considerable number of germs formed gas during the later tests when they had not done so during the earlier ones.

The fermentation tube has been largely used in the past to differentiate closely related species. It might be concluded in the light of the contradictory results which have been obtained in this study that the fermentation test is really of little value for this purpose. Such a general conclusion does not logically follow from this data because the particular group of organisms which have been studied here chance to lie on the very border line of visible gas formation and accordingly are not typical of germ life in general.

The fact that this group does lie on the border line of visible gas formation is shown by the fact that the amount of gas is small in most cases, in some cases only a small bubble appearing in the fermentation tube, and also by the failure of even this small amount of gas to appear in a considerable proportion of the tests with some of the strains.

The crudeness of the fermentation tube as a measure of the total gas formation is well brought out by Keyes.[24] He found in his study of *B. coli* that the total gas produced under comparable conditions in the fermentation tube and in a vacuum were in the ratio of 12.4 to 99.9.

In considering the importance which should be attached to the results obtained with the fermentation tube it should be remembered that all forms of living protoplasm respire gases and with the bacteria the carbon dioxide of respiration is an easily measurable quantity even with those forms which show no evidence of gas formation in the fermentation tube. The

[24]Keyes, F. G. The gas production of *Bacillus coli*. *Jour. Med. Research*, N. S., 16: 69–82. 1909.

failure of the gas to appear in the tube is due to its solution in the liquid media and partial diffusion through the open arm of the tube. The ability of the liquid to hold appreciable amount of gas in solution is illustrated by the bubbles of gas which appear in the top of the tube after the medium has been heated in the sterilizing process and again disappear on cooling.

While exact measurements are lacking it is probable that the gas of respiration does not nearly saturate the fluid in the fermentation tube so that the appearance of gas in the closed arm does not mark the beginning of the true fermentative action but rather a somewhat advanced stage of this action. Conversely, when dealing with a group of cultures which are on the turning point of the formation of visible gas, the failure of the gas to appear does not necessarily mean that the ability to ferment the sugar in question has been lost but rather that it has been so diminished as not to supersaturate the fluid in the tube. The fact of the continuation of the growth in the closed arm and of the formation of acid in these fermentation tube cultures lends color to the idea that the sugar is still being attacked in the same general way though less vigorously than before.

CLASSIFICATION.

Classification in a case like this may serve either of two distinct ends. It may assist future students to recognize the relationships of cultures which they may study and it may be of service to the farmer in showing whether the form which is present on a given crop will be dangerous to a succeeding crop which he may desire to grow later on the same soil. Because of the limited knowledge of germ life which is now available, any classification of such forms must be considered as tentative and as merely expressing the judgment of the authors concerning the relationships under discussion. In this connection it should be stated that some of the doubtful points in this classification were referred to six of our friends whose judgment was considered as of especial value in such matters. There was such a wide variation in what they con-

sidered the proper course to follow that it has seemed best to confine the present publication largely to a presentation of the facts as observed and leave at least the more complicated portion of the classification until after the discussion of the pathology of these cultures.

It was brought out in Table II that these 43 cultures are practically identical with regard to the 38 headings under which they were there compared and that the only observed differences were those of fermentative ability which were clearly expressed by the group numbers.

It is seen from Table III that the first 15 cultures there given are identical in their fermentative ability in that all of them produce visible gas in the fermentation tube from dextrose, lactose and saccharose. If the principle is accepted that a single well demonstrated, positive result is conclusive the 18 additional cultures down to and including Miller Stalk 3 No. 1 must be held to be identical with the first 15.

Of this group of 33 cultures having the group number B. 221.1113022, *Bacillus carotovorus* Jones is the oldest described species and should be taken as the true representative of this collection of cultures. The two other cultures which have been described in literature as bacterial species, *Bacillus omnivorus* van Hall and *Bacillus oleraceae* Harrison, are clearly identical with *Bacillus carotovorus* and there is no further occasion for continuing to recognize them as distinct species.

Continuing the arrangement of the cultures on the basis of the results from the fermentation tube the next group would have the group number B. 221.1123022 and is represented by the single strain Vermont XLVIII. This culture ferments dextrose and lactose with visible gas formation, but no apparent gas is formed from saccahrose.

Mathematically the next group has the group number B. 221.1213022 and is likewise represented by a single strain, Vermont C. This group is characterized by the failure to form visible gas from lactose.

The next possibility is the failure to form gas from dextrose while forming it from the other two sugars under considera-

tion and this group with a group number of B. 221.2113022 is represented by Vermont LIV and 0.2e. The faintness of the boundaries between these groups is shown by the case of 0.2e where in two determinations gas was actually formed in a single fermentation tube in each case. This result has not been accepted as conclusive because in neither case were the results from the accompanying tubes accordant.

The next group bears the group number B. 221.2123022 and is represented by Potter's Bacillus and Riverhead Stalk 3 No. 1. The former is a good illustration of the group while the latter forms a connecting link with the following group, since while it formed visible gas from lactose in the earlier tests it failed to do so during the latter studies and but for the earlier determinations would be included in the following group.

The series of groups is closed with a group of four cultures in which there was no visible gas formed from any of the sugars at any of the tests. This has a group number of B. 221.2223022 and *Bacillus aroideae* Townsend, is the only named species. Spieckermann's Bacillus was isolated and described at an earlier date, but was not given a specific name.

Summarizing this arrangement on the basis of the results from the fermentation tube test with dextrose, lactose and saccharose we have the following:

B. 221.1113022 *Bacillus carotovorus* Jones and 32 other cultures.

B. 221.1123022 Vermont XLVIII.

B. 221.1213022 Vermont C.

B. 221.2113022 Vermont LVI and 1 other culture.

B. 221.2123022 Potter's Bacillus and 1 other culture.

B. 221.2223022 *Bacillus aroideae* and 3 other cultures.

It will be observed that the two possible groups of .221 and .122 are not represented. It is really surprising that in a collection of 43 cultures there should have been examples of six different groups and there is no apparent reason why a study of a larger number of cultures should not bring out these missing ones.

The above arrangement is one which will appeal to the students of this field because it clearly summarizes the observed results and provides a type for all of the cultures which will be found except those which belong to the missing groups above referred to. Unfortunately this clearness of classification is more apparent than real, since practically each successive determination of the collection of cultures led to a rearrangement of the representatives of the various groups with a gradual shifting toward the upper groups because of the greater importance placed on a positive result than on a negative one. The final accumulation of 33 cultures in the upper group is largely the expression of the continued action of the law of chance and had the study continued longer this group would undoubtedly have been correspondingly enlarged.

An inspection of Table III shows that while some of the organisms gave constant results at the various determinations a considerable number vibrated from one end of the above set of group numbers to the other at different determinations, often being classed temporarily with a number of the intermediate groups. Under such circumstances the above classification is seen to represent divisions which are too shifting and transient to be designated as species.

While the authors do not desire to be dogmatic in this connection the conception has been forced upon them during this study extending over a series of years that they were dealing with a group of organisms which were very closely related and which combined a remarkable stability and uniformity with regard to practically all of their culture characteristics with a remarkable variability with regard to the results from the fermentation tube test with certain sugars. It would seem that the correct explanation of this apparent variability was the fact that the entire group had a very weak fermentative ability and the gas formed from the sugars in question was approximately equal to the amount required to saturate the fluid in the fermentation tube and provide for the diffusion which is unavoidable in that test. With the changes

in the fermentative vigor of the culture, concerning the details of which comparatively little is known, the amount of gas produced fluctuates above and below this saturation point giving the accompanying positive and negative results based on the presence or absence of visible gas in the closed arm of the fermentation tube.

The important fact of this fluctuation having been recognized it is a matter of little consequence to the scientist whether it is maintained that there are six species or only one. It should be mentioned in passing that the idea of species as originally conceived is entirely inapplicable to bacteria since it was based on morphological similarity coupled with an ability to produce fertile offspring. Morphologically the entire bacterial world can be divided into only a few groups and sexual reproduction is entirely lacking. In the present instance it seems to the authors that the only possible basis for recognizing more than one so-called species in connection with the present group of cultures must lie in the relation of the parasite to the host and since that part of the subject will be treated in a succeeding publication the matter of classification will be dropped at this point.

DETAILED DESCRIPTION.

On the Classification Card of the American Society of Bacteriologists in addition to the group number and the material given in Table II, there is a provision for the detailed characteristics of the organism in question. It was the original intention to present this description for the typical representative of each of the groups of cultures as given above, but when these descriptions had been prepared it was found that they were practically verbatim copies with the exception of the fermentation of sugar which has already been discussed. Accordingly the description of *Bacillus carotovorus* Jones will be given and with the exceptions just noted this may be accepted as applying to the entire collection of cultures.

Bacillus carotovorus Jones.

For group number and brief characterization see page 110.

I. MORPHOLOGY.

1. Vegetative cells. Medium used, agar slope at 20-25° C. 1-2 days old; Form, *short rods, long rods, short chains, long chains;* Limits of size, .7 to 1 x 1.5 to 5; Size of majority, .8 by 2; Ends, *rounded.*
3. Endospores, *none.*
4. Flagella, 2 to 10; Attachment, *peritrichiate;* How stained, *Pitfield, Löwits, Fischer.*
5. Capsules, *none.*
6. Pseudozoogloea, *present, slight.*
7. Involution forms, *not observed.*
8. Staining reactions. Stains well in *watery fuchsin, gentian violet, carbol fuchsin, Loeffler's alkaline methylene blue;* Gram, *negative.*

II. CULTURAL FEATURES.

1. Agar slope. Growth, *abundant;* Form of growth, *filiform* to *spreading;* Elevation of growth, *effuse* to *raised;* Luster, *glistening;* Typography, *smooth* to *contoured;* Optical characters, *opaque* to *opalescent.*
2. Potato. Growth, *moderate* to *abundant;* Form of growth, *filiform* to *spreading;* Elevation, *effuse* to *raised;* Lustre, *glistening;* Typography, *smooth* to *contoured;* Chromogenesis, *white on all media;* Odor, *decided;* Consistency, *butyrous;* Medium, *grayed*, but *not discolored* in the customary meaning of that term.
4. Agar stab. Growth, *best at top, abundant, wide-spreading;* Line of puncture, *filiform.*
5. Gelatin stab. Growth, *best at top;* Line of puncture, *filiform;* Liquefaction, *crateriform* to *infundibuliform;* Begins on *2d day* at 20° C.; Complete in *6 days* with some cultures and *not in months* with others.

6. Nutrient broth. Surface growth, *pellicle thin* and *sometimes absent;* Clouding, *moderate* to *strong, persistent;* Odor, *decided;* Sediment, *compact* to *flocculent, usually abundant.*
7. Milk. Coagulation, *usually on 3d day* at 20° C.; Coagulum, *very slowly and slightly peptonized,* and not complete *in months,* digestion *not clearly evident to the eye;* Medium, slightly *browned.*
8. Litmus milk. *Acid, litmus reduced.*
9. Gelatin colonies. Growth, *rapid;* Form, *punctiform* to *round;* Depression, *crateriform;* Edge, *entire;* Liquefaction, *saucer.*
10. Agar colonies. Growth, *rapid* at 20–25° C.; Form, *round, occasionally irregular,* deep colonies *fusiform;* Surface, *smooth;* Elevation, *raised* to *convex;* Edge, *entire* to *undulate;* internal structure, *amorphous* to *coarsely granular* or even *grumose.*
13. Cohn's solution, *no growth.*
14. Uschinsky's solution, *abundant.*
18. Best medium for long continued growth is peptone bouillon.
19. Quick test for differential purposes. Slices of uncooked carrots, turnips and cabbages.

III. PHYSICAL AND BIOCHEMICAL FEATURES.

1. Fermentation tubes. Gas[25] produced in small amounts from *dextrose, lactose* and *saccharose,* but not from *glycerine;* Growth in the closed arm with *dextrose, lactose* and *saccharose,* but not with *glycerine;* Acid produced from *dextrose, lactose, saccharose* and *glycerine.*
3. Nitrates in nitrate broth *reduced* to *nitrites.*
4. Indol production *feeble.*
7. Optimum reaction for growth in bouillon in terms of Fuller's scale, 0.

[25] See page 117.

8. Vitality on culture media, *moderate.*
9. Temperature relations. Thermal death point, 48–50° C.; Optimum, 25–30° C.; Maximum, above 38° C.; Minimum, below 10° C.
10. Killed *readily* by drying.
12. Sunlight. Exposure, not on ice, at midday in Sept. showed decrease after 1 minute, increasing to destruction of 90–100 per ct. after 20 minutes.

IV. Pathogenic to many fleshy vegetables of the North Temperate Zone.

CONCLUSIONS.

A considerable number of the cultivated plants in the North temperate zone suffer at times from a bacterial soft rot caused by a non-chromogenic, liquefying bacillus.

This comparative study of forty-three pathogenic strains derived from six different vegetables indicates that the results of fermentation tube tests with dextrose, lactose and saccharose offer the only usable cultural basis for differentiating these strains. However the cultures of the entire group have a weak fermentative power which, with very few exceptions, produces only a little more than enough gas to become evident in the fermentation tube. At other times the same strains produce no gas at all. These variations make the results of the fermentation tube test an unsatisfactory basis for classification.

Unless later studies of the pathogenicity of these cultures shall offer a basis for subdividing them, there is no apparent reason why they should not all be considered as somewhat variant members of a single botanical species.

II. PECTINASE, THE CYTOLYTIC ENZYM PRODUCED BY BACILLUS CAROTOVORUS AND CERTAIN OTHER SOFT-ROT ORGANISMS.[1]

L. R. JONES.

INTRODUCTION.

Two of our earlier publications (1900, 1901) have given detailed accounts of a bacterial soft rot of carrot and other vegetables due to the organism, *Bacillus carotovorus*. In the first of these articles it is stated (1901 :304,312)[2] that "microscopic examination of the decaying carrot tissues has shown that the organism invades the intercellular spaces, and multiplies there with enormous rapidity. The middle lamellae of the adjacent cells appear to be softened or destroyed by the secretions of the bacteria, since isolation of the cells in invaded tissue occurs, but the bacteria have not been observed in the interior of the cells of the recently disorganized tissues. .... This (action on the middle lamella) is probably due to an enzym of the nature of cytase excreted by the bacteria. .... It seems probable that the further study of the bacteria concerned with the soft rots of plants will swell the list to a considerable number of organisms which resemble the above and each other more or less closely in their physiological characters."

FIG. 1. CARROT-ROOT PARENCHYMA IN EARLY STAGE OF DECAY CAUSED BY *B. carotovorus*.
The cytoplasm is plasmolyzed and the bacteria confined to the intercellulars except where the wall has suffered mechanical rupture, as in the upper left-hand cell.

It appears, therefore, that a fuller understanding of the cell-wall-dissolving or other enzyms produced by such bacteria is desirable for two practical reasons: First,

[1] The laboratory studies upon the enzym here discussed were made during the years 1901–04, and this manuscript was prepared at their completion in 1904. Owing to the plan of co-operation, as explained in Part I, this

because the parasitism in each case seems directly associated with and probably dependent upon the power to produce such an enzym. Second, because these soft rot organisms are so much alike as to make the question of their specific relationship an extremely complex one which must ultimately be settled largely by appeal to physiological characters, including their ability in parasitism, and it would seem that their enzym production might prove of value in this connection as a differential character. Another interesting question of fundamental importance concerns the relationship of the cytolytic enzyms, or cytases, from various sources. We have attempted to determine whether the enzym here dealt with is identical with those obtained by de Bary (1886)[2] and Ward (1888) from certain fungi, by Brown and Morris (1890) and later investigators from seeds and by Potter (1899) and others from soft rot bacteria.

In the progress of these investigations a detailed study was first made of the enzym as produced by the carrot-rot organism, including a comparison of its action when secured in various ways apart from the living bacillus, and also as observed upon the sundry vegetable tissues. Thereafter a comparison was undertaken of the characteristics of the enzyms secured from the soft-rot organisms of several other vegetables and finally with wall-dissolving enzyms produced by other classes of bacteria, by fungi and by germinating seeds. In the following discussion of the results it will conduce to clearness and directness of statements to follow a somewhat similar order. It might seem more logical to begin with a

publication has awaited the conclusion of the associated morphological studies, except for a summarized account of the work which appeared in the "Centralblatt für Bakteriologie und Parasitenkunde," 1905, (see Bibliography). Inasmuch as no important contribution to the subject has come to our attention meanwhile, it has seemed best to leave the manuscript unaltered, and to add no titles to the bibliography later than 1905.

An important part of the work of the author was done in the botanical laboratory of the University of Michigan where he profited from the advice of Professor F. C. Newcombe. In the investigations carried on in his own laboratory in Vermont, valuable assistance was had from two of his students, Messrs. H. D. Bone and L. P. Sprague. He gratefully acknowledges his indebtedness to these gentlemen.

[2]All citations to the bibliography follow the plan of giving in parenthesis after the author's name the year of publication, followed where desired with the page numbers specificially referred to.

detailed discussion of the action of the enzym upon cell walls. In pursuance of the above plan, this is deferred and it must here suffice to state that the action consists in the softening and swelling of the walls and ultimately in the complete solution of their middle lamellae in susceptible vegetable tissues, but that in all cases it stops short of complete solution of the cell membrane, a residue of cellulose always remaining.

The studies here reported upon were carried on at various times during the years 1901–1904. The strain of the carrot-rot organism used has been the same throughout and is that isolated from decaying carrot tissues in 1899 and since carried in culture, practically all of the time in beef broth, at the ordinary laboratory temperature, 16°–22° C.

The question has arisen as to whether during this time reduction has occurred in pathogenicity and rate of enzym production. Van Hall (1903) found that his iris rot organisms lost pathogenicity to iris after only four weeks in laboratory culture and his experience with these led him to expect this as a rule with such organisms. Laurent's (1889) and Lepoutres' (1902) experiments suggest a like probability. Potter (1900:445) found no such rapid loss of pathogenicity in his turnip rot organism.

In the case of *B. carotovorus* there has, in our judgment, been a considerable decrease in pathogenicity since our first trials of 1899. The change has, however, been a gradual one rather than rapid or radical, and, therefore, difficult to estimate. The virulence and rate of invasion of tissues has always varied with vegetables and environmental conditions, but it is certainly less vigorous in attacking even the more susceptible plants now than it was in our earlier inoculation experiments. A culture of ths organism was sent to Messrs. Harding and Stewart of the New York Experiment Station in 1902. They reported it actively pathogenic at first, 1902, but wrote us a year later that it had lost practically all pathogenicity. Meanwhile our own cultures had not changed in any such radical way. In this connection it is worthy of remark that Harding and Stewart kept their cultures on agar whereas ours were carried in broth. *B. carotovorus* is

remarkably sensitive to desiccation as shown in our earlier work (1900:328). It seems to us not unlikely that the weakening observed at the New York Station may have resulted from the intermittent desiccation incident to its culture on agar.

Exact estimates as to relative ability in enzym production shown now and formerly are even more difficult to make than are those as to pathogenicity. Our first isolations of enzym were made in 1901. We have compared some of the preserved samples of these earlier enzyms with those isolated in 1903. Those of 1901 were certainly more active than those of 1903. This difference might, however, possibly be accounted for by variations in medium and vigor of development as shown later in this article.

In our judgment, along with the loss of pathogenicity there has been a corresponding decline in enzym-producing power, but both of these have been so gradual as to be hard to estimate quantitatively.

The first thing undertaken in the course of these investigations was to determine whether the softening of the tissues associated with the invasion of this bacillus was certainly due to an enzym, and whether, if so, the enzym was separable from the organism. Five methods were tried with the object of securing such enzym, if it existed, apart from the organism, viz., (1) heat, (2) filtration, (3) germicides, (4) diffusion through agar, (5) precipitation by alcohol.

The first three methods involved, in all cases alike, the following procedures: The cultivation of the organism in beef broth for periods varying from three to fourteen days; the treatment of such cultures by the methods under trial; the determination of the sterility in the broth so treated; in case sterility was secured, the testing of the cytolytic activity of this sterilized broth by immersion in it of sterile blocks cut from fresh uncooked carrot or turnip roots, or from potato tubers or of cotyledon of immature pea; finally, tests to determine the continued sterility of the broth during this last trial period. In all cases where chemicals were used control trials were made to be sure that the chemical itself was not the cause of the changes observed.

STUDIES WHEREIN THE ENZYM WAS ISOLATED BY HEATING.

The thermal death point of the carrot-rot bacillus was carefully determined in connection with our earlier studies. It was found that recently inoculated thin-walled-tube cultures immersed for ten minutes at 51° C., or slightly under this, are rendered sterile.[3]

Previous studies (cf. Green, 1901: 98) upon cytolytic enzyms have shown that when in solution they are destroyed by heating to a temperature of 60°–65° C. It seemed probable, assuming that we are dealing with the same or a similar enzym, that there might be an intermediate temperature where the organism would be destroyed and the enzym left in the solution. This matter was tested by cultivating the organism in beef broth, heating these cultures to sterilize, making transfers to prove sterility and inserting bits of sterile carrot or other fresh vegetable tissues to determine enzym action.

The details of a single experiment will suffice to make clear the methods and aid in interpreting the results.

A series of six 10 c. c. beef broth cultures seven days old were immersed for ten minutes in a water bath of which the temperature was held at 55° C. These tubes were of thin glass about 15 x 1.5 cm. in size, immersed in the water three-fourths of their depth. The original reaction of the broth was +1.5%. To make sure of continued sterility transfers were made from the tubes soon after leaving the bath and again at the close of the experiment. Immediately after heating, a small block of living carrot tissue, cut from the interior of the root with proper precautions to insure sterility, was inserted into each tube. Like blocks of tissue were put into control tubes of each of two kinds, first, sterile uninoculated broth, and second, living broth cultures of the same age as the ones heated. The result was that the tissues in sterile uninoculated broth remained unsoftened, those in the living cultures rapidly softened and were fully decomposed in three

[3] The above trials were first made in 1899 and repeated with like results in 1901. A careful repetition in 1903, using the same methods, showed a thermal death point fully one degree lower. This is doubtless the result of long cultivation in the laboratory. It is simply a matter of biological interest, which does not in any way affect the methods or results of the enzym studies discussed above.

or four days, while those in the heated tubes showed a similar but slower softening, requiring ten days for full action.

In other experiments sterile blocks cut from turnip root and cotyledons of immature peas were used and were similarly softened. The results were fairly uniform and satisfactory. Various cultures so exposed at temperatures of 54°, 55°, 58°, 60°, 62°, 63°, 64°, 65°, 68°, 73° were rendered sterile in practically all cases. There was distinct cytolytic action in the sterile broths heated at the lower temperatures and none in those heated at the higher. There was, however, evident inhibition of activity even at the lowest of these as is shown in the experiment just described. Heating at 60°–62° inhibited the action to a marked degree as compared with 58° and in all cases, except one, heating at 62° entirely checked the activity. In only one case did any action occur in tubes heated at 63° and that was probably explainable on the ground of erroneous reading of temperature, since a repetition of the work gave results in harmony with the other series. No action occurred in any tube heated above 63°. The point of total inhibition of the cytolytic action as determined by this method, therefore, lay at or about 62° and there was marked decrease at all temperatures above 58°. Certain temperature relations will further be discussed later.

STUDIES WHEREIN THE ENZYM WAS SECURED BY FILTRATION.

It seemed probable that if the enzym were in solution outside the bodies of the bacilli it would pass through the porcelain bacterial filters and so be obtained apart from the organisms. Broth cultures of ages varying from seven to fourteen days growth have on six different occasions and with different bougies been passed through the Pasteur-Chamberland filters and the sterility and enzym content of the filtrate tested. There has been no difficulty in securing sterility with Pasteur-Chamberland filters, although earlier attempts with thinner walled and probably less perfect bougies were not successful.

Numerous trials were made by immersing in this sterile filtrate sterile cubical blocks cut from fresh roots of carrot and turnip and from potato tubers and also cotyledons of young peas, either fresh or those which had been for some time in sterile broth. In all cases alike these tissues were softened with solution of the middle lamella as in the presence of the living organisms. The detailed record of a single experiment will suffice.

In each of six tubes containing 10 c. c. of the sterile filtrate was introduced a carrot block about 3 mm. in diameter. At the end of twenty-four hours there was perceptible softening over the surface of these blocks and at the end of three days they were softened throughout. Potato blocks of similar size tested in the same way showed the first signs of softening on the fifth day and required ten days for complete softening.

These experiments and other similar ones that might be cited, including trials with razor sections under the miscroscope, showed that the lamella-dissolving enzym was in solution in the broth outside of the bodies of the bacilli. The question arose, however, as to whether the filtrate possessed the full enzymic activity of the original broth. It is conceivable that the bodies of the bacilli contain much of the enzym which gradually diffuses into the external liquid even after their death, and also conceivable that the filter may retain some of the enzym which was diffused in the original broth. To gain information on these points the enzymic activity of the filtered sterile broth was compared at various times with unfiltered broth cultures and with cultures of broths sterilized by the addition of chemicals. In one series of trials thin razor sections from roots of each carrot and turnip were immersed in (a) culture broth sterilized by filtration, (b) culture broth sterilized by a 20% addition of chloroform, (c) solutions of alcoholic precipitate from culture broth. The solutions (b) and (c) acted about alike, whereas (a) required at least twice as long to disintegrate the tissues Similar trials made later using razor sections of turnip showed no difference of importance between the cultures containing the living organism

and sterile broths like (b) and solutions like (c). A detailed discussion of these points occurs later.

Similarly sterile blocks from living carrot root were placed in the filtrate in comparison with like blocks in living cultures and others in broth plus 10% of chloroform to sterilize. The latter were shaken thoroughly and sterility proved. The carrot tissues in the living cultures and in the tubes sterilized by chloroform were alike softened in three days, whereas the blocks in the filtrate were more slowly acted upon, requiring nine days for full action. Still further evidence of this relation of filtration to enzym content was obtained by the method of alcoholic precipitation to be discussed later. Samples of filtered and unfiltered cultures were rendered 80% alcoholic and the filtered yielded only one-fourth as much of the enzym-containing precipitate as did the unfiltered. Moreover five per ct. solutions of each of these tested upon razor sections of carrot and turnip showed the enzymic action of the unfiltered fully twice as rapid as that of the filtered. Taking into consideration both the relative amounts and the relative strengths of these solutions, it would seem from this last trial that possibly four-fifths of the enzym was lost by filtration through the porcelain.

Comparisons and conclusions.—All these experiments give like evidence that passage through the Pasteur-Chamberland filters as used in these trials reduces decidedly the enzym content of the broth, although it does not remove all of it. Just why this retention of the enzym occurs has not been determined. As already suggested, this may be in part, at least, the enzym contained within the bacterial cells and which would later diffuse into the surrounding liquid; or it may be in part or wholly external to these cells either closely associated with the bodies of the bacteria and so retained with the bacterial slime in the porcelain; or it may be that the filter removes some of the enzym content which is diffused or in solution in the broth. The results of Freudenreich (1899) point to the latter conclusion. He attempted to clarify cheese extract for qualitative analysis by passing through Chamberland fil-

ters He found that although the crystallizable and diffusible nitrogenous compounds (amids) passed through the bougies, some 90% of the soluble protein matter might be held back. Although all the bougies used by him retained considerable of the nitrogenous matter his trials showed that this passed much more fully through a new one than through the same after it had been used several times. In later trials (1900) he passed milk through these filters and found that the enzym galactase was removed thereby.

These experiments of Freudenreich came to our attention after we had completed our filtration experiments. In reviewing our records in their light we find that we used new filters or those which had been used for similar work only a few times. We are assured, therefore, that even the new bougies largely reduced the enzym content and that none that we employed, some of which had been used several times, wholly eliminated it.

The results of others who have tested the relation of filtration to enzym content of cultures of similar soft-rot bacteria may profitably be reviewed in this connection.

Potter (1900. 448) found that filtration through Pasteur-Chamberland filter did not remove the enzym produced by his *Pseudomonas destructans*. Laurent (1899) found similar bacterial enzyms to pass through porcelain while Spieckermann (1902) found that after passing culture broths through the Reichel porcelain filter the sterile broth had not the least enzymic action. Van Hall (1902) found that the juice expressed from potato decayed by the invasion of *B. subtilis* when passed through the porcelain filter retained the property of rapidly destroying the potato tissue. He also found (*Zeitschr. f. Pflkr.*, 1903) similar but weakened action in the juice from iris invaded by his *Bacillus omnivorus*, when this was passed through a porcelain filter. In other trials he found filtered broths lost all activity. We are at a loss to reconcile some of these results with our own and the others except by appealing to differences in the filters.

STUDIES WHEREIN THE ENZYM WAS ISOLATED BY THE USE OF GERMICIDES.

The preceding results were satisfactory so far as they went, but it was manifestly desirable to find some simpler method of procedure. Two serious objections to the preceding methods should be eliminated if possible, namely, first, that precautions are necessary to insure the sterility of the broths during prolonged study subsequent to filtration; and, second, the ever-present danger that the method used to eliminate the organism may at the same time remove or weaken the enzym. It seemed probable from the experience of others who have studied similar enzyms that some chemical added to the cultures would kill or wholly inhibit the bacillus without destroying the enzym or interfering with its activity. With this hope, trial was made of additions of formalin, phenol, thymol, and chloroform, respectively, to beef broth cultures. In considering the results reference was also made to related experiments, to be discussed in detail later, where similar additions of these chemicals have been made to solutions of the enzym-containing alcoholic precipitates.

FORMALIN.

The relation of formalin, both to the life of the organism and to the activity of the precipitated enzym, has been determined. It has been found that both the organism and the enzym are extremely sensitive to this chemical. Since, however, the organism is more so it is possible so to gage the amount as to sterilize the broth and leave the enzym active. These conclusions are based upon experiments made by the addition of varying proportions of formalin, both to the beef broth cultures and to solutions of the precipitated enzym. Some hundreds of such additions have been made to beef broth cultures, including the following strengths, and numerous trials each of many of them: Formalin, 0.03%, 0.06%, 0.08%, 0.095%, 0.18%, 0.33%, 0.46%, 0.57%.

The detailed account of a single series will suffice to explain the general method and results. All this work was carried on at temperatures of 18°–22° C.

To ten broth tube cultures, 10 c. c. each, formalin was added as follows and the tubes then thoroughly shaken: Two tubes (1 & 1′), 0.57% formalin; two tubes (2 & 2′), 0.46%; two tubes (3 & 3′), 0.33%; two tubes (4 & 4′), 0.18%; two tubes (5 & 5′) 0.095%. Two tubes (6 & 6′) containing sterile broth were included to serve as controls. On the third day transfers made from these to sterile broth proved the sterility of all. On the fifth day a sterile cube 5 mm. in diameter, cut from the interior of fresh carrot was inserted into each tube. On the eleventh day the carrot tissues in tubes 1, 1′, 2, 2′, 3, 3′ 6, 6′, were not softened; those in 4, 4′, 5, 5′, were completely softened. On the fourteenth day 3, 3′, were softened somewhat; others unchanged. On the twenty-third day 3, 3′, further softened; 2, 2′ softened somewhat but less than 3, 3′. On the thirty-third day 1, 1′, and 6, 6′, showed no softening; others completely softened. Final transfers to sterile broth showed all tubes sterile at the close of the trial.

As a result of similar series, repeating the above and using other strengths of formalin, the following conclusions have been reached. The addition of 0.1% formalin is sufficient to sterilize a beef broth culture of *B. carotovorus* one to ten days old, providing the tube is thoroughly shaken. More formalin, 0.2% or even more, may be needed if not thoroughly shaken. The presence of 0.6% or more formalin completely inhibits enzym action; amounts as low as 0.3% retard to a marked degree. There was perceptible retardation from 0.06% formalin, although this amount was too slight to sterilize with certainty. In all the above trials the formalin acted on the broth several days before its relation to the enzymic activity was determined.

Trials were also made to determine the effect of formalin additions to solutions of the enzym obtained from broth cultures by precipitation with alcohol. The activity in these cases was determined by trial on razor sections of carrot roots. The results were in accord with those just discussed, viz., a slight but appreciable retardation from 0.05% addition, and almost complete inhibition where 0.5% was added. In these latter trials the formalin was added to the enzym solution some time before the cytolytic activity of the mixture was

determined. The results led us to abandon further work with formalin.

After the preceding work with formalin was completed, however, Spieckermann's article (1902: 166) reached our hands in which he reports that a 0.2% solution of formalin sterilized the cultures of the soft-rot organism of cabbage with which he was working and did not inhibit the action of the cytolytic enzym, *at least for several hours.* We, therefore, undertook to learn the relative rate of action of formalin upon each, *B. carotovorus* and its enzym, by adding to broth cultures 0.2% of formalin, shaking thoroughly and testing both viability and enzym action at frequent intervals. It was found in the first series of trials that at the end of twenty-four hours the activity of the enzym was not appreciably lessened, at the end of forty-eight hours there was slight retardation and this was pronounced at the end of seventy-two hours. On the other hand transfers at the end of only three hours showed most of the organisms to be dead or so affected that growth was slow in starting and at the end of forty-eight hours the broth was sterile.

In a second series of trials the broths were tested at more frequent intervals. This again showed the organisms to be killed before the enzym was fully destroyed, but the retardation was more pronounced than in the preceding trials. The details are as follows:

1. Action on enzym:—Broth cultures six days old; formalin added to make 0.2% solution, thoroughly shaken; cytolytic action compared with control tubes by testing upon thin sections of turnip. Result: After three hours slight retardation was evident; after six hours nearly twice as long a time was required for the same results in the formalin solution, i. e., formalin retarded the action 50%; after twenty-four hours still more difference; after forty-eight hours formalin solution required five times as long as control; after eighteen days it required sixty hours to disorganize sections, whereas the control broth did this in one hour.

In a third series, little if any retardation up to the sixth hour; after nine hours the action of the formalin broth re-

quired twice as long; after twenty-four hours it required four times as long.

2. Actions on the organism:—Formalin to make 0.2% solution was added to broth cultures, thoroughly shaken; transfers at the end of each two, three, six, and nine hours showed growth. There was, however, progressive retardation. Thus the control was clouded in less than twenty-four hours; that made at the end of two hours showed clouding first on the third day; that at the end of three hours first clouded on the fifth day; six hours, on the seventh day; nine hours, on the twelfth day. After clouding appeared growth progressed with normal rapidity.

These results show sufficient variation between the different trials to forbid sweeping generalizations. They agree, however, with each other and with Spieckermann's results in showing that the action on the organism is more rapid than on the enzym. There was no appreciable retardation of the enzym action until after a period varying from three to nine hours, or in one case twenty-four hours, whereas there was marked inhibition in growth of the organisms after two or three hours. These results were of such a nature, however, as to discourage us from looking to the use of formalin as a practical method of sterilizing broths preparatory to the study of the normal action of the enzym. If used within two or three hours as Spieckermann directs, sterility is not insured; if a longer time elapses, the activity of the enzym will be reduced quantitatively at least and conceivably affected qualitatively.

Bliss and Novy (1899: 52) have shown that fibrin, which has been acted upon for a short time by formalin, resists thereafter the digestive action of proteolytic enzyms. These observations raised the question as to whether the retardation in the cytolytic action already noted might be in any degree the result of the action of the formalin on the wall of the vegetable tissues rather than upon the enzym itself. In order to determine this, razor sections of turnip and radish were immersed twenty-four hours in full strength formalin, then washed out in water, and the rapidity of action of enzym solution on these compared with that on freshly cut sections

and on those which had lain twenty-four hours in absolute alcohol. Other similar trials were made where the tissues had lain a month in either formalin or in absolute alcohol, respectively. All were promptly and similarly decomposed, there being no evidence of difference in this respect. The inhibiting action of formalin must, therefore, be attributed to its effect on the enzym itself rather than on the tissues. It is interesting to note in this connection that Bliss and Novy (1899: 79) found formalin to inhibit certain enzyms (papain, trypsin, amylopsin) and not others (pepsin, malt diastase). Von Freudenreich (1900), experimenting upon milk enzyms, found that formalin tends to lessen the action of galactase more promptly than it does that of pepsin and pancreatin.

It is surprising that Potter (1900: 448) was apparently unable to destroy with formalin the organism causing white rot of turnip. We are led from our experiments to believe that larger amounts of formalin or more thorough agitation would have accomplished this.

PHENOL.

Seven trials of this, each involving several cultures, were made with uniformly satisfactory results. A piece of the crystal varying in size from one-fourth to one-half that of a pea (i. e., making 0.3% to 0.6% solution) added to a 10 c. c. broth culture and well shaken has never failed to produce sterility and there is apparently no retardation of the activity of the enzym. To cite a single experiment:

A crystal of phenol half size of a pea, i. e., making about 0.5% solution was added to each of six 10 c. c. broth cultures six days old and thoroughly shaken. On the second day thereafter transfers were made to test sterility. No growth having developed from these transfers seven days later, sterility was inferred and a cube of sterile fresh carrot about 5 mm. in diameter was added to each tube. In two days' time all those pieces of carrots were fully softened. When compared with other tubes sterilized by thymol or chloroform and with those containing the living organism such phenol tubes showed no evidence of retardation.

In other trials it was found that additions of 0.1% and less of phenol failed to sterilize and, on the other hand, additions of 5% or more totally inhibited the activity of the enzym. The phenol was added to the culture in these experiments four days before the enzymic activity was tested.

THYMOL.

This proved less satisfactory as a germicide than phenol, but chiefly, we think, because of its slight solubility and slow diffusion in the broth. If the alcoholic solution is used the thymol is precipitated upon contact with water, hence there is no gain. Our trials have shown that powdered thymol, which floats on the surface of a broth culture, will sterilize the surface layer, but that where the culture has stood without shaking, living organisms persist, at least for many days in the deeper parts of the broth. For this reason even large amounts of thymol will fail to sterilize in the absence of agitation, whereas sterility can be secured with small amounts by thorough shaking. The following experiments will serve to show this.

A large excess of thymol (2%) was added to each of ten broth tube cultures eight days old and a small amount (about 0.2%) to each of ten similar tubes. All of these were left without agitation. Transfers made on the eighth day thereafter showed living organisms in four of the tubes containing the larger amount of thymol and in five of those with the smaller amount. On the tenth day living organisms remained in three tubes of each series. In another series a crystal of thymol equalling about 0.2% of the broth was added to each of three ten c. c. broth tube cultures four days old and a tiny crystal of about one-fourth this size to each of three other similar cultures. These were all thoroughly shaken. Transfers from these tubes on the second day thereafter showed living organisms in all three of these containing the lesser amount, but the others were sterile. In all cases pieces of sterile carrot inserted into tubes sterilized by thymol have been quickly softened without evidence of inhibition.

In comparison with the above results it is of interest to note that Potter failed to sterilize cultures of his turnip white-rot organism by the use of thymol (1900: 448); but the possibility remains that more agitation would have secured sterility in his cultures.

E. F. Smith (1901) found that certain organisms will grow in beef broth in the presence of thymol, but his statements would indicate that there was little or no agitation of the broth. These results force us to question whether full dependence can be placed on some of the results of Bourquelot and Herissey's work on pectin enzyms, as discussed later in this article, since they, apparently, depend on additions of thymol water to insure sterility.

CHLOROFORM.

Since this is the agent usually employed in enzym studies for the inhibition of bacterial growth especial attention has been given to the determination of its relation both to the organism and the enzym.

The first experiments to determine this were carried out in 1901. In these Powers & Weightmann chloroform of "U. S. P. standard" strength was used. This was added to broth tube cultures, seven to nine days old, in amounts to give proportions varying in different experiments from 10% to 50%. These tubes were shaken, then allowed to stand and stratify. The excess of chloroform promptly settled to the bottom, but such tubes continued to emit a strong odor of chloroform throughout the experiments. Transfers made three days later show the cultures to contain living organisms in all cases.

During the year 1903, these trials were repeated, using both Mallinckbrodt's "M. C. W. purified" chloroform and the "U. S. P." grades both of this firm and of Powers and Weightmann. These later results were alike in all trials and differed from those made in 1901. In every one of these later cases where 10% or more of chloroform was used and *the tubes thoroughly shaken* sterility was secured.

The details of a single trial will suffice to illustrate the method and results. Chloroform was added as follows to each of six c. c. broth tube cultures, six days old, shaking very thoroughly; to tubes 1 & 1′ added 1 c. c. of chloroform; to tubes 2 & 2′ added 0.5 c. c. of chloroform; to tubes 3 & 3′ added 0.3 c. c. of chloroform. On the third day thereafter transfers from these showed 1 & 1′ to be sterile, whereas the others contained living organisms. On the fifth day transfers from these latter again showed living organisms. Cubical blocks of fresh carrot were placed in tubes thus sterilized with 10% additions of chloroform and in other similar series sterilized by 25% and 50% additions respectively, and in all cases alike they were quickly and fully softened.

There was no appreciable retardation in the rate of softening in any such case as compared with tubes sterilized with thymol or phenol, or even with cultures containing the living organisms.

This matter was of so much importance that further comparative trials were made by using razor sections of turnip. There was no appreciable difference in the rate of softening as between living cultures and those sterilized by chloroform. Thus in one trial, broth cultures four days old were used; 10% of chloroform was added to each of two of these; after thorough shaking immediate trials were made comparing the activity with that of similar cultures; no difference was found. Again, at the end of the sixth day when the chloroform tubes were sterile, comparative trials showed the sterile broth to equal in enzymic activity the living control cultures, now ten days old.

Comparisons and final conclusions.— These results showed chloroform to have no inhibiting effect upon the enzym when used even in great excess and proved the efficiency of chloroform as a germicidal agent in such work as we were doing. At the same time they emphasize the need of painstaking and caution if chloroform is relied upon, either to sterilize cultures or to preserve sterility of enzym solutions as is so frequently done.

A comparison of these results with those obtained by others will again prove helpful.

Brown and Escombe (1898: 16) satisfied themselves that the cytolytic enzym of barley is not appreciably weakened in its action by a saturated aqueous solution of chloroform. Smith (1901) has called attention to the fact that many organisms are surprisingly resistant to chloroform and emphasized the point we have just made, as to the need of caution in its use. Potter (1900: 448) did not succeed in sterilizing cultures of the turnip white-rot organism with chloroform, but Spieckermann (1902: 166) found chloroform effective for sterilizing the sap of vegetables invaded by his kale rot organism. He does not state the amount used nor the method of agitation, but it was, presumably, used liberally, and thoroughly shaken. He reports no appreciable retardation of the enzym by it unless it be a gradual weakening after long standing of fifteen days or more. His results were, therefore, similar to ours.

Van Hall (1903) used chloroform in his work upon his *Bacillus omnivorus*. His results are surprisingly at variance with those of all these others, since he found the addition of even 0.5% of chloroform destroyed all trace of activity in bacterial juices in one-fourth of an hour. We are unable to reconcile this with our experience and in view of all the evidence must believe him in error in his interpretation of results.

A COMPARISON OF THESE GERMICIDES.

The trials of the chemicals previously mentioned were conducted at about the same time and there were frequent opportunities for comparisons. Toward the close of the work a special series of trials was planned as follows in order to reach more definite conclusions upon the comparative effect of these chemicals on the activity of the enzym.

A series of ten broth cultures (10 c. c. each) five days old was treated as follows:

To each of two tubes No. 1 & 1′ added 1 c. c. of purified chloroform making 10% solutions. To each of two tubes No. 2 & 2′ added 0.5 c. c. of 2% formalin making 0.1% solutions. To each of two tubes No. 3 & 3′ crystal of thymol (about 0.05 g., i. e. 0.5%). To each of two tubes No. 4 & 4′ crystal

of phenol (about 0.5 g., i. e., 5%). Two other tubes were included in the series; one of these, No. 5, contained sterile broth in which the organism had grown for seven days and which had then been rendered sterile by passage through the Pasteur-Chamberland filter. The other, No. 6, contained a living culture of the organism, five days old. Three days later transfers made from each tube except the last proved sterility. On the same day a sterile cube cut from living carrot root was inserted into each of these tubes. Forty-eight hours thereafter the carrot tissue in tubes 1, 1′, 3, 3′, 4, 4′ and 6 were alike well softened, there being no evidence of inhibition by any of these chemicals and no greater softening in the presence of the living organisms than in these sterile tubes. The carrot in the filtrate (5) was considerably less acted upon and formalin (2 & 2′) showed still less softening. Further examination showed full softening in these latter tubes (2, 2′ & 5) at the end of nine days. Transfers at the close of the experiment proved continued sterility in all the tubes except one of those containing chloroform.

These confirmed the evidence from previous trials and led us to conclude that neither chloroform, thymol nor phenol had any inhibiting effect on the enzym; that well developed broth cultures sterilized by the addition of any of these possessed as active cytolytic properties as that in which the organisms continued alive; that formalin inhibited the enzymic activity; that filtration through porcelain reduced the enzym content.

To preclude the possibility of error because of the softening action upon the vegetable tissues of the broth itself, or of any of these chemicals, a series of control tubes was held in which carrot blocks were immersed in sterile broth without any added chemical and in similar ones in which the various chemicals were added in the amounts indicated in the above experiments. These carrot tissues in all cases remained unsoftened.

SECURING THE ENZYM BY DIFFUSION.

Our observations upon decaying vegetables have shown that the cell walls are affected some distance in advance of the invasion of the organisms. This would indicate the diffusion

of the enzym through the intermediate tissues as was observed by de Barry (1886) in the case of *Peziza* and by others with similar parasitic invasions. When this first came to our attention it suggested the possibility of testing the diffusibility of the enzym through some medium impenetrable to the bacteria, partly as confirmatory of the above explanation and partly as another method of studying the action of the enzym apart from the organisms. Before we got to the point of undertaking this, however, van Hall's (1902: 649) paper came to hand in which he describes his similar attempts and their very interesting results. In his studies upon his *Bacillus omnivorus* he employed a modification of the plan developed by Beijerinck in his studies upon the mosaic disease of tobacco. Van Hall's method consisted in growing his organism in streak cultures upon the surface of agar, then cutting off a surface layer from this, carrying the streak, and transplanting the layer to potato. In this way he secured the softening of the potato underneath the streak. In other cases he removed sterile bits of agar underlying the culture and transplanted them to sterile vegetable surfaces for trial.

We found the method outlined in the following experiment a more convenient way of securing the same result.

Beet broth agar, two per cent, was poured into small petri dishes to a depth of about 3 mm. When this had hardened and the surface dried slightly, *Bacillus carotovorus* was implanted on the surface of a small area at the center. At the end of three days a good surface growth was thus secured about 1 cm. in diameter. A slice somewhat larger than this layer of agar was then cut from the interior of a fresh turnip root and placed in a large sterile petri dish, using caution to avoid contamination. The layer of agar from the smaller dish was then carefully lifted with sterile instruments and placed upon the surface of this turnip slice in the larger dish and covered to prevent contamination. This was designated A. The details of the method may become clearer upon examination of the accompanying figure. Two other dishes, B and C, were prepared in like manner at the same time. A layer of sterile agar was laid in a fourth dish upon a turnip slice as a control and designated D.

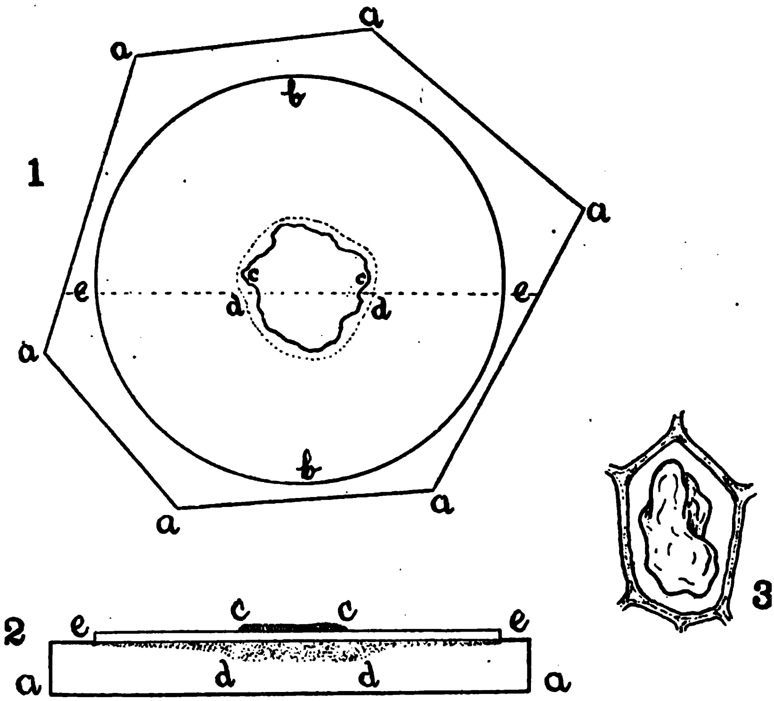

FIG. 2. DIAGRAMS TO SHOW METHOD AND RESULTS OF TESTING THE DIFFUSIBILITY OF THE ENZYM THROUGH AGAR.

No. 1, surface view; 2, vertical section of the same along dotted line e–e; a–a, sterile slice of living turnip root; b–b, layer of nutrient agar bearing the bacterial colony c–c; d–d, region of most active enzymic action; the extent of softened tissue at the end of 24 hours is indicated by the dotted area in No. 2; No. 3 shows a single cell of this softened turnip tissue.

At the end of twenty-four hours, examination of this control, D. showed the turnip underneath the agar to be unchanged, except for a slight yellowish stain imparted by the agar to the surface; no softening whatever had developed. Upon lifting the agar in the first dish, A, the turnip showed an area immediately underlying the colony and somewhat larger than the surface spread of this in which the tissues were slightly browned and softened exactly as where invaded by the organism. Bits of this rotten turnip tissue were im-

mediately transferred to each of three broth tubes to test sterility. In none of these, neither in any of several similarly tested later, did growth develop, showing beyond question that this softening of the tissues was due solely to the bacterial products which diffused through the layer of agar from the surface colony above. Upon more carefully examining the turnip slice it was found that there was a slight softening of the surface over the entire area covered by the agar, b–b, of the diagram Fig. 2. The area immediately underlying the colony was softened much more deeply however viz., about 1–1½mm. The deepest softening occurred in a circle about 2 mm. wide underlying the margin of the colony, lying between d and d in the accompanying diagram, (Fig 2). Microscopic examination showed exactly similar conditions to those which accompany bacterial invasion, viz., isolation of the cells as a result of the solution of the middle lamellae, with the residual walls swollen and taking a blue stain upon treatment with chlor-zinc-iodide, and the protoplasmic contents showing granulation and plasmolysis.

Several other dishes examined after twenty-four to thirty-six hours show results practically like the above except that in most of them the softening was to a uniform depth of 1-2 mm. immediately underlying the colonies with a gradual decrease in this depth, as shown in the accompanying diagram which is drawn to exact scale as to size of colony and degree of softening at the end of twenty-four hours.

In connection with the above work we also conducted similar transplantations of colony-bearing layers of agar to the surface of sterile gelatin plates. Examination in such cases at the end of three days revealed liquefaction of the gelatin underlying the colony, but for an area equalling about twice the diameter of the colony above, and to a depth of one to two millimeters. Transfers from this liquefied gelatin to broth tubes proved its sterility and showed that the action here, as in the case of the vegetable tissues, was due to the diffusion of the bacterial products from the colony through the intervening agar.

SECURING THE ENZYM BY PRECIPITATION WITH ALCOHOL.

Strong alcohol added to bacterial culture broths gives a flocculent whitish precipitate which includes not only the enzyms present, and various proteid matters, but also carries the bodies of the bacteria down with it. This is the commonest method of securing enzyms in bacteriological investigations and is, therefore, in a measure a standard for comparative work. It also has advantages over the other methods especially in that it is possible easily to preserve this dried precipitate for indefinite periods. For these combined reasons it was used in much of our work. We have found that 25 per cent of alcohol is fatal to the carrot-rot organism in broth cultures and since more than that amount was used in all our precipitation work, it is evident that this method insures the elimination of the living organism.

METHODS.

Several questions arose at the beginning as to methods which we will discuss under the following heads:

1. *Filtration.*—The first of these was as to whether the alcohol should be added directly to the culture broth, thus giving a precipitate containing the bodies of the bacteria, or whether it is preferable to remove the bacteria by passing the broth through a porcelain filter before precipitation. The trial reported on a preceding page showed that the filtered broth when tested directly possesses less enzymic activity than does the unfiltered broth. As is there shown, the precipitate obtained when such broth is rendered 80% alcoholic similarly has less enzymic strength than the precipitate from unfiltered broth. After a few trials had determined these facts all subsequent work along this line was with culture broths which had simply been passed through filter paper.[4] This filter re-

[4] Some students of cytolytic enzyms have objected to the use of filter paper because of the possible action of the enzym upon it. This occurred to us early in our work but repeated observations have shown this enzym is entirely inactive on the celluloses proper. We have, therefore, used Schleicher & Schull's filter paper, both for filtering the broths and for collecting the precipitate.

moves the coarser deposits but not the bodies of the bacteria. To the filtrate was then added enough 95% alcohol to render it alcoholic to the desired degree, usually 80%, the precipitate allowed to settle, the supernatant alcohol siphoned off, the precipitate, collected on filter paper, washed with either 95% or absolute alcohol and quickly dried, partially in a current of warm air, then in a desiccator over sulphuric acid. The dried precipitate, which is gray and somewhat brittle, was then powdered before redissolving in water. It is of course important to secure quick drying to avoid the possibility of alteration as a result of bacterial growth or of chemical changes in the precipitate. The drying must also be done at so low a temperature as to preclude danger of injury from heat to the sensitive enzym. In our earlier work we washed out the 95% alcohol with absolute alcohol in order to hasten the drying. Later it was found this made scarcely any difference in the time and no difference in the result, providing the moist precipitate was properly broken up so as to dry out quickly. Spieckermann (1902: 165) used absolute alcohol followed by ether, presumably to secure quick drying. Most of our work had been completed before his paper reached us, but we thereupon tested this method in comparison with that followed by us and have found it unsatisfactory. The precipitate when the ether was used showed a diminution in its enzymic activity providing it stood in the ether long enough to displace the alcohol. Thus, holding the precipitate in ether one hour, while it did not injure it, made no appreciable difference in its rate of drying; where in ether fifteen hours, it was only two-thirds as active and required almost as long for drying; where in ether for twenty-four hours it dried quickly, but possessed only one-fourth the activity of that dried directly from 95% alcohol. While a solution of the latter softened radish and turnip tissues in fifteen minutes, the former required one hour to accomplish the same result.

In further trials chloroform was used with part of the precipitate and ether with another part to remove the alcohol with a view to hastening the drying. Thus one-half of the

precipitate was dried immediately after washing with 95% alcohol. The balance was immersed for nineteen hours in absolute alcohol, then for forty-eight hours in chloroform,[5] changing the chloroform once during this pediod. Upon its removal from this fluid the precipitate quickly dried to a chalky, brittle, white mass. Comparative trials, using 5% aqueous solutions of the precipitate dried from the 95% alcohol and that where the chloroform was used, showed them to be equally active. These results established our confidence in the method of drying directly from 95% alcohol and we have therefore continued so to do as it is more economical of both chemicals and time. We would again say, however, that its most successful use is in our judgment conditioned upon quick drying secured by breaking up the moist precipitate and placing it in a current of dry, warm air. Inasmuch as we found the use of ether injurious to the enzym and van Hall (1903) says that chloroform destroyed it in his trials, it is at least incumbent on anyone who employs either of them to determine their safety. It is, of course, possible that even with the same enzym secured from different broths and in mixture with different compounds there might be different results with the same chloroform or ether, and even more likely that some brands of ether or chloroform might carry in solution substances acting deleteriously upon so sensitive a compound as these enzyms.

2. *The most favorable strength of alcohol.*—Precipitation with various percents of alcohol was tried early in the work to determine the relative amounts and strengths of the precipitates thus secured.

In the first trial, using beef broth cultures five days old and increasing the alcohol at four steps, fractional precipitates were secured as follows:

At alcoholic strength of 20%, a mere trace of precipitate was secured.

At alcoholic strength of 40%, secured 15% of total precipitate.

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[5] Mallinckbrodt's "M.C.W." brand.

At alcoholic strength of 80%, secured 80% of total precipitate.

At alcoholic strength of 90%, secured 5% of total precipitate.

Trial of the last three precipitates (i. e., 40%, 80%, 90%) on carrot sections showed all to have cytolytic activity, but that from the 90% had distinctly less than did the others. Between those of 40% and 80% there was no noteworthy difference. In a second trial the culture broth was divided into three lots of 150 c. c. each, and each lot treated separately as follows:

Lot 1, made 40% alcoholic, gave 0.005 g. precipitate, or 1% of total.

Lot 2, made 60% alcoholic, gave 0.065 g. precipitate, or 14% of total.

Lot 3, made 80% alcoholic, gave 0.390 g. precipitate, or 85% of total.

Trials of these precipitates on carrot and radish sections showed those from lots 2 and 3 to be of excellent activity and about alike, whereas that from 1 required twice as long to soften the sections.

Since in both of these trials the 80% alcohol secnred practically all of the enzym, and this in a state of the highest activity, that strength alone was used in all subsequent alcoholic precipitation work.

3. *Reprecipitation.*—The precipitate obtained by the addition of alcohol to the broth is, of course, composed only in part of the enzym, the larger portion being presumably other proteid matter. In the hope of securing a purer state of the enzym a re-solution and second precipitation with alcohol was made as follows:

Two grams of the dry powdered precipitate obtained from beef broth cultures was added to 400 c.c. of distilled water, the solution placed on ice and frequently shaken. At the end of four hours one-half was filtered off and, since filtering through paper did not remove the undissolved precipitate, it was clarified by passing through a porcelain filter, then reprecipitated by rendering 80% alcoholic. The balance stood

twenty-four hours on ice and was then filtered through six inches of calcined sand. This cleared it up but slightly. Sufficient alcohol to make this an 80% solution was added and the precipitate collected and dried. Comparisons were then made between like solutions of this reprecipitate, of that passed through the porcelain filter, and of the original. That passed through the filter was scarcely equal to the original in strength; that passed through the sand was slightly stronger, but not enough so to be of practical consequence. Reprecipitation was therefore considered of little advantage and was not tried further.

4. *The relation of strength of solution to activity.*—When this dried alcoholic precipitate is added to water it swells promptly, but apparently only a small fraction of it is dissolved. Two questions arose early in our work; first, as to the relation of the strength of this solution to the activity of the enzym; second, as to the relative enzymic activity of (a) such solutions of the precipitated enzym and (b) of the original broth cultures from which the precipitates were secured.

To determine the first point amounts equal to 1%, 5% and 10% respectively were added to distilled water, plus chloroform, and their relative activities compared on carrot and turnip root sections. The results in all cases showed the activity to increase with strength of solution, but not proportionately. The average of several trials led to the conclusion that, with the precipitate used, it required twenty-five minutes in the 1% solution to secure as complete enzymic action as was secured in fifteen minutes in the 5% solution and in ten minutes in the 10% solution; that is to say, the relative activities of the 1%, 5% and 10% solutions stand in the ratio of 6, 10 and 15.

Our practice in all of the work here reported with alcoholic precipitates has been to use 5% solutions unless otherwise stated.

The second question is of quite as great interest, since it involves the query as to whether the enzym is or is not injured by the action of the alcohol.

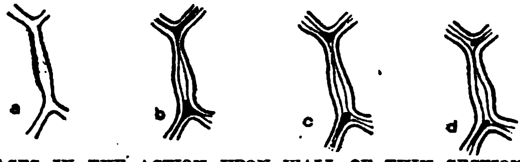

FIG. 3. STAGES IN THE ACTION UPON WALL OF THIN SECTION OF CARROT ROOT IMMERSED IN A 5 PER CENT SOLUTION OF THE BACTERIAL ENZYM SECURED BY PRECIPITATION WITH ALCOHOL.

Normal wall shown in a; b, same, 7 minutes after immersion; c, after 13 minutes; d, after 30 minutes action only minute traces of the middle lamella remained. The cells lose coherence after the stage shown at b is reached (Camera lucida).

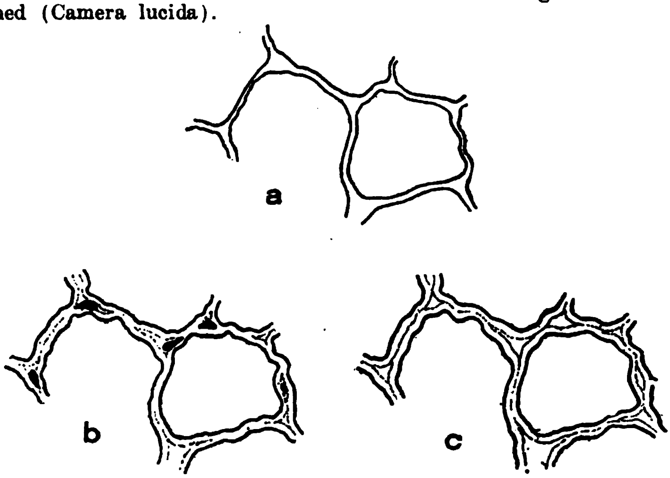

FIG. 4. A SERIES OF CAMERA DRAWINGS FROM ANOTHER SECTION OF CARROT ROOT IMMERSED IN 5 PER CENT SOLUTION OF THE ENZYMIC PRECIPITATE.

The normal walls shown at a; b, the same after 12 minutes; c, the same after 32 minutes action.

In general, the beef or vegetable broth cultures yielded from 0.2 g. to 0.4 g. of the dry alcoholic precipitate for each 100 c.c. of broth. It is evident that the 1% solutions of this precipitate should contain some three times as much of the enzym as did the original broth cultures, providing that the precipitation and the re-solution are complete. On the other hand it is quite conceivable that the enzym may be injured by precipitation, in which case the aqueous solution of the precipitate might show weaker enzymic action than the original broth.

To test this matter a portion of the precipitate from a six day beef broth culture was added to a volume of water equalling that of the original broth (0.015 g. of precipitate in 5 c. c. of water, equalling 0.3% solution). The activity of this solution was then compared with that of a like broth culture sterilized by the addition of chloroform, and of third sterilized by passage through a Pasteur-Chamberland filter. The results were that the first and second showed practically the same degree of enzymic activity, whereas the third showed less than half as much. These comparative trials were repeated on a later occasion. Here we used (a) the juice expressed from a turnip decayed by *B. carotovorus,* inoculated three days previously; (b) an aqueous solution of the alcoholic precipitate obtained from a similarly decayed turnip, so made up that the volume of water equalled that in the original juice from which the precipitate came. No chloroform was added to (a), the living culture being used. Trials of these on turnip and carrot sections showed the enzymic activity of (b) to be fully as great as that of (a). The results of Spieckermann (1902: 166), which reached us after the earlier trials were made, are in accord with these. It is surprising that no loss occurs through precipitation and re-solution of a compound so sensitive as this enzym shows itself to be in many ways.

In these trials the original broths and the aqueous solutions of a strength equalling them have proved on the average less than one-third as active as the 5% solutions which we have used in most of our trials with the precipitate; that is to say, these 5% solutions have rotted the vegetable sections in less than one-third the time required to do this where the sections are immersed in the living cultures.

RELATION OF CULTURAL CONDITIONS TO ENZYM PRODUCTION.

THE MEDIUM.

The vigor of growth of the organism varies widely, of course, with the composition of the medium and with other cultural

conditions such as age and temperature. Various experiments were undertaken to determine the relation of these matters to enzym formation, having in mind especially the conclusions of some previous investigators that enzym production in certain cases is a starvation phenomenon.

De Bary (1886) looked upon the disorganization products of the enzym of *Peziza sclerotiorum*, which dissolves the middle lamella of the cell walls of various plant tissues, as the chief source of the nutrition of the fungus mycelium. He thought some sugar, available as food for the fungus, to be the product of the enzym action on the host cell walls. He considered, however, that the enzym was similarly concerned with action upon the protoplasm of the host.

Ward (1888) concluded that the similar wall-dissolving enzym produced by the lily Botrytis is a starvation phenomenon. Brown and Morris (1890) consider starvation to be a stimulus to cytase as well as diastase secretion in germinating barley. They also (1893) found that diastase formation occurs more actively in leaves during the night and concluded that this is attributable to the exhaustion at that time of soluble food, and hence is to be classed as a starvation phenomenon.

Careful comparisons have been made as to the enzym product from growths upon several media[6] varying widely in nutritive elements and especially in carbohydrate content. These have included:

1. Dunham's peptone solution (1% Witte's peptone, 0.5% sodium chloride); a medium upon which this organism makes a very weakly growth.

2. The same plus 2% cane sugar. In this the organism makes a poor growth as compared with beef broth, but the clouding is estimated to be twice as dense as in the simple Dunham's solution. This growth is of short duration, however, owing, probably, to development of acidity, which inhibits or even kills the organism.

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[6] For details as to composition of the various culture media used in our work and the relative development of the organisms on these media, see Vt. Sta. Rpt., **13**: 314. (1900.)

3. Neutral beef broth; the standard medium used in our work and one upon which the organism makes a good growth.

4. The same plus 2% cane sugar; a medium in which the growth is more rapid than in plain broth.

5. Cooked carrot broths. Two kinds have been used:

(a) Those in which equal weights of pieces of fresh carrot roots and of water were cooked and sterilized together by the fractional process in the steamer.

(b) The same in which, after the first cooking in the steamer, the roots were crushed and the liquid expressed and filtered through several thicknesses of paper to remove all of the cell-wall substance, then this filtrate returned to the flask and sterilized in the steamer by the fractional process. Both of these have, except in certain cases discussed below, proved to be the best of cooked media for this organism.

6. Living vegetables. Fresh living roots of carrot and turnip are both quickly invaded and rotted by this organism, furnishing apparently ideal nutritive conditions. The expressed juice from such recently decayed vegetables[7] was used in comparison with the preceding broth cultures 1-5.

The results were in general determined by comparing on razor sections of carrot and turnip roots the cytolytic action of like solutions of the alcoholic precipitates obtained from the above culture liquids.

The sixth method, using fresh uncooked vegetable, has given the most active enzym product as well as the largest amount thereof. In comparison with beef broth, which yields on an average about 0.25% of dry precipitate (i. e., 0.5 g. of dry precipitate from a 200 c.c. broth culture), this expressed juice from decayed turnip after filtration through paper has yielded over 0.5% of a precipitate, a 5% aqueous solution of which

[7] These were, of course, so handled as to insure pure growths of the organism. This was most surely and satisfactorily done by taking several roots, washing thoroughly, soaking twenty minutes in 0.1% solution of corrosive sublimate, rinsing in sterile water, then with precautions against contamination removing the surface to a depth of 0.5 to 1 cm., cutting thick pieces from the interior tissues and laying in sterile petri dishes. Inoculations on the surface of these at temperature 20°–24° secured their decay in two to three days.

caused the complete rotting of a razor section from a turnip in ten minutes, whereas a like solution of the precipitate from a beef broth culture required nearly two hours. Thus the former scheme not only gave twice as much precipitate but a solution thereof twelve times as active as was a like solution of the latter. Another comparison was made by immersing the section directly in the living cultures, i. e., in the expressed juice of decaying turnip and in beef broth cultures of the same age, viz., four days. Turnip sections so immersed were fully rotted in twenty-five minutes in the turnip juice, whereas fifty minutes was required to do this in the beef broth culture; in other words, the former was fully twice as active as was the latter. In other trials the difference was even more marked, the vegetable juice being three times as active as were the broth cultures.

The precipitates from the cooked vegetable broths, (a) and (b) of the fifth group have behaved about alike, indicating that the presence or absence of cell-wall substance has no effect on enzym production. Where a good growth has occurred, somewhat more precipitate was secured than from beef broth, which approximated but did not quite equal in weight that from the living tissues in enzymic activity. Since these were not secured and tested at the same time it is not possible to make exact comparisons. We have not, however, found these cooked vegetable media uniformly satisfactory.[8] In some

[8] We have had some puzzling experiences with such cooked vegetable broths, both of carrot and turnip. In our earlier trials (1900–01) they proved satisfactory media. In later ones (1902–03) they were unsatisfactory, this organism and various other soft-rot organisms failing to make strong growths in them. We have been forced to attribute this to the development of inhibiting poisonous compounds as a result of the cooking. It is known that cooking at high temperatures in the autclave may develop poisonous compounds in vegetable broths which will completely inhibit bacterial growths. Dr. F. G. Novy advises us that these are probably decomposition products of the carbohydrates. We have, therefore, never autoclaved such vegetable broths, but always sterilized by discontinuous cooking in the steamer. After experiencing the above troubles we tried cooking at still lower temperatures, in one case below 80% but the results were no more satisfactory. Thinking the difficulty might be in the glassware, we used very carefully cleaned Jena glass flasks but this seemed to make no difference. These differences are not associated with any marked loss of pathogenicity or other changes that we could detect in the organism and we were forced to attribute them to variations in the vegetable used.

cases excellent growths have developed, in others but weakly ones. In the former, as already stated, active enzymic development occurred, in the latter very little, i. e., the enzymic development was directly proportional to the vigor of growth. The beef broth cultures have given less active enzyms than these vegetable media, as has been explained. We have, however, continued to use beef broth largely in our comparative studies for the reason that the enzymic activity is sufficient for those purposes and more reliance can be placed upon the uniformity of the medium. The addition of 2 per ct. sucrose leads to more vigorous growth of the organism, especially in the earlier stages before too great acidity developed, and it is significant that more of the precipitate and with more enzymic activity was developed in the sugar broth (medium No. 4) than in the plain broth (medium No. 3).

Thus companion cultures of these two media nine days old, of which the sugar broth showed an acid reaction (+4.2 per ct.) and the plain broth was practically neutral (+0.7 per ct.), were rendered 80 per ct. alcoholic. The sugar broth yielded 0.3 per ct. of dry precipitate, the plain broth 0.25 per ct. A comparison of these cultures on carrot sections showed the former to be twice as active as was the latter, i. e., to soften a like section in one-half the time. A repetition with these two media, precipitating on the sixth day, gave similar differences but a little less marked. The Dunham peptone solution has proved a very poor medium whether with or without the addition of sugar. The alcoholic precipitate from such cultures seven days old (media Nos. 1 and 2 above) have shown scarcely appreciable enzym content.

In conclusion, then, we may note that there seems a perfect correlation between the rate and vigor of the growth of the organism and the amount of enzym developed, i. e., the more vigorous the growth the more enzym; that the presence of cell wall substance had no appreciable effect on the amount of enzym developed; and that in beef broth cultures the addi-

tion of sugar, which favors growth, also increased the enzym production.

There is nothing whatever here, therefore, to indicate that this enzymic production is a starvation phenomenon, but rather to the contrary, since the more vigorous the growth the more the enzym; moreover, the addition of carbohydrate food (sugar) seemed to stimulate enzym production, whereas the presence or absence of cell wall tissue seemed without effect. This last fact suggests the idea that the organism makes little or no use for nutritive purposes of the wall substance which it dissolves.

THE AGE OF THE CULTURE.

The enzym content was compared in carrot broth cultures (grown at 20–22° C.) of the respective ages of one and a half, three, five, seven, and nine days. A rapid increase was found from a scarcely distinguishable activity in the precipitate from the one and a half days' growth to a large amount from that of five days, and a continued but slower increase to the strongest action from the oldest cultures, viz., nine days. It was noteworthy that the increased degree of enzymic activity in the precipitates from these carrot broth cultures was accompanied by a like increase in the degree of rottenness of the vegetable tissues in the culture flasks.[9]

With cultures made in beef broth grown at laboratory temperature the results were less marked than those just recorded for the carrot broths. The outcome in the series showing most positive differences is indicated herewith. Each culture consisted of 150 c.c. of broth neutral to phenolphthalein:

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[9] L. H Jones, a student in our labatory, working upon another (undetermined) species of soft-rot organism reached like conclusions. Thus he found that cultures in potato broth eight days old gave an enzym less than one-half as active as were similar cultures sixteen days old. While a 5% solution of the alcoholic precipitate from eight days' growth required twenty-five minutes to decompose a turnip section, like solutions from the sixteen days' growth rotted the sections in ten minutes. When the eight day culture flask was opened it was found that the potato blocks were not fully softened, but when the sixteen day flask was opened the blocks were completely rotten.

Culture No.	Age when tested.	Reaction	Amount of Precipitate.
1	3 days	—2.2%	0.495 g.
2	6 "	—1.0%	0.460 "
3	9 "	—0.9%	0.474
4	17 "	neutral	0.445 "

Like solutions (5 per ct.) of these precipitates tested on carrot sections showed all to contain the enzym, the activity of the solution increasing with the age of the culture. There was distinctly more in 2 than 1; the difference between 3 and 2 was very slight and that between 4 and 3 not great. Another similar series of cultures of ages four, six, nine and eighteen days respectively showed practically like enzym activities. The amount of enzym here, as in the trials with broths of different composition, seemed directly proportioned to the amount of growth. In carrot broths the growth is slower in starting than in beef broth and persists in its increase for a longer time. This slower start in comparison with beef broth is very likely due to the excess of organic acids present in the vegetable broth and to the further increase in acidity during the early development before the soluble carbohydrates are used up. In the neutral beef broth this inhibiting influence is not present and the bacterial development is at its height in about four or five days, as judged by the degree of cloudiness of the broth. Here, as in the preceding trials, there is no evidence that the enzym formation is a starvation phenomenon, but rather the reverse—viz., the more vigorous development is accompanied by more enzym production. Moreover, the enzym after its excretion into the broth appears to be a fairly stable compound, hence tends to accumulate with the age of the culture. R. E. Smith (1902) develops a theory of the parasitism of *Botrytis cinerea* somewhat at variance with Ward's idea that the enzym development is a starvation phenomenon, and more in accord with our own observations on this bacillus. Smith's conclusion is that the fungus in the absence of abundant food cannot develop the wall-dissolving enzym. It can, however, develop a toxin which kills the host tissues. He regards the initial penetration of the host tissues by spore tubes following this as

merely mechanical. Later, having acquired "vital energy" as a result of higher nutriment, the production of the wall-dissolving enzym occurs and this aids in the subsequent spread of the fungus through the host tissues.

TEMPERATURE.

The optimum temperature for most rapid growth of *B. carotovorus* is in the neighborhood of 28° to 30° C., i. e., tubes will show clouding more quickly at this than at lower or higher temperatures. The presumption would seem to be that enzym production would be most active at this temperature, but our trials have shown otherwise. Where the enzymic activity of precipitates from broth cultures grown for eight days in the incubator at a constant temperature of 30° C. were tested in comparison with those grown at room temperature (18° to 22°), the latter have shown distinctly more enzym than those grown in the incubator. We can offer no satisfactory explanation for this. Possibly comparisons at an earlier stage, say at three days' growth, would have shown somewhat different results. It is also possible that the difference is due to less aeration in the flasks held at the constant incubator temperature than occurs in those at the frequently fluctuating room temperature. It is evident that this lack of aeration would have more inhibiting influence with the older growths than with the early clouding. The result convinced us that better enzym production could be had outside than inside the incubator, and since making these trials all our cultures have been carried at room temperatures.

RELATION OF VARIOUS CONDITIONS TO THE ACTIVITY OF THE ENZYM.

EFFECT OF LONG KEEPING.

It is difficult to measure and record the rate of activity of such an enzym with a sufficient degree of accuracy to make exact comparisons. We have not succeeded in doing this to our entire satisfaction. So far as we can judge, however,

there is no loss where the dried enzym-containing precipitate is kept for months or even years. Thus two samples of precipitates prepared and carefully tested in May, 1901, were kept and again tested in May, 1903, when so far as we could judge their activity was as great as when prepared two years before.

Spieckermann (1902: 166) states that the activity of the similarly dried enzym precipate obtained from his kale-rot organism was undiminished after four months in the dry state.

RELATION OF TEMPERATURE TO ACTIVITY.

Temperature relations were studied, using solutions of the alcoholic precipitate from carrot broth cultures and testing them on carrot sections. It was found that the action was slight at 2° C., good at 22°, better at 32°, best at about 42°, inhibited somewhat at 48°, showed pronounced inhibition at 50° and was practically or entirely checked at 51° and above. For example, the action was nearly twice as rapid at 42° as at 22°; and at 32° it was practically midway in rate between the higher and the lower. The optimum lay between 40° and 45°. When such solutions were held at various temperatures up to 49° for an hour, either in the presence or the absence of carrot tissues the enzym was uninjured, i. e., they showed normal activity when the temperature was lowered again. If, however, the heating was carried to 51° or above for ten minutes, whether in the presence or absence of carrot tissue, little if any action ensued thereafter.

A comparison of these results using the precipitated enzym with those described earlier in this article where the original broth was used, shows that the points of inhibition and destruction were approximately ten degrees lower in the solutions of the precipitate.

It is interesting in this connection to recall (cf. Green 1901: 448) that observations upon invertase have shown that it withstands a temperature higher by 25° C., when cane sugar, upon which it acts, is present than it does in its absence. A similar variation, though not so extreme, has been observed

with several other enzyms. This suggests that, in general, an enzym may enter into such a relation, either with the substance upon which it acts or with some other compound associated with it in solution, that as a result it may receive some protection against the injurious action of heat or other deleterious agencies. It is, of course, possible that the enzym in the original broth is in such relation to some organic matter as to be thus protected, but our attempts to protect it by the presence of carrot tissues in these experiments were unsuccessful since, as stated above, it was destroyed at the same temperature whether in the presence or the absence of the carrot sections. It is to be noted, however, that we were working here with the alcoholic precipitate redissolved in water. Woods (1899) has shown that the oxydizing enzyms of the maple leaf withstand higher temperature when in the juices of the plant than when in the presence of alcohol.

In comparison with our results it is interesting to note that Brown and Morris (1890) found 35°–40° C. an especially favorable temperature for the cytolytic enzym of germinating barley, whereas it became decidedly less energetic at 50° and was almost completely paralyzed at 60°.

EFFECT OF ACIDS AND ALKALIES.

The organism as studied was found to be parasitic on various vegetables, all of which possess an acid cell sap. In the course of its development, however, it renders the sap alkaline. It appears of interest, therefore, in connection with the question of the parasitism of the organism to learn the relation of the reaction of the medium to the activity of the enzym. This was investigated, using the alcoholic precipitate obtained from carrot broth cultures. Solutions of this were made in distilled water containing additions of the chemicals under trial and their activity tested on razor sections of carrot. The strength of the acid and alkali solutions was in all cases determined by titration against phenolphthalein.

Alkali.— It was found that the presence of sodium hydroxide titrating —2% inhibited the reaction slightly, and that the

inhibition increased with the further addition of the alkali up to —10%, where it was total.

Acids.[10] — A very slight addition of hydrochloric acid seemed favorable to the action of the enzym, a reaction of +0.5% being about the optimum. The difference between this and the neutral solution was, however, slight. When the reaction was +2.5% or above there was great inhibition and at +5% it was practically complete.

Various organic acids were tested also, the results in detail being as follows:

Acid.	Strength of titration.		Effect.
Oxalic.............	+0.8	percent.	retarded slightly.
"	+1.1	"	" greatly.
"	+8.0	"	complete inhibition.
Acetic.............	+0.2	"	no effect.
"	+0.5	"	" "
"	+1.0	"	retarded greatly.
"	+10.0	"	complete inhibition.
Formic............	+0.15	"	no effect.
"	+0.4	"	" "
"	+0.75	"	retarded greatly.
"	+7.5	"	complete inhibition.
Tartaric...........	+0.14	"	no effect.
"	+0.55	"	" " (possibly slight retarding).
"	+5.5	"	almost full inhibition.
Malic.............	+0.2	"	no effect.
"	+0.8	"	" "
"	+8.0	"	almost full inhibition.
Citric.............	+0.2	"	no effect.
"	+0.8	"	" "
"	+8.0	"	almost full inhibition.

From these results it will be seen that these organic acids in no case aided the action; that where the acidity, as shown by titration, was +0.5% and less they were practically without effect; that +1.0% and above distinctly inhibited in all cases where it was tried, and that from +5% to +10% led to complete inhibition. Here again it should be noted that even this large amount represents only a very mild degree of acidity, viz., 0.5% more or less by weight.

[10] These acids were made up by weight and titration strength determined afterward. One per cent. gravimetric solutions titrated respectively as follows: hydrochloric +50; acetic +20; tartaric +11; citric +15.5; malic +15.5; formic +15.

EFFECT OF PLANT JUICES.

Inasmuch as in the cases of actual decay of vegetables the enzym must occur in solution in the cell sap, it is of interest to learn whether the normally acid sap tends to retard its action as do the organic acids mentioned above. Two series of trials were made to determine this. In the first the juice was expressed from living tissues of each, carrot, radish and ripe tomato. These were tested by adding to each, respectively, equal parts of a 5% aqueous solution of the precipitated enzym from a carrot broth culture. The result was, therefore, a 2.5% solution of the precipitate in half-strength vegetable juice. There was slight retardation in all cases in the rate of action as compared with solutions in distilled water, this being a little more pronounced in the case of the tomato. The test was repeated with the tomato juice by dissolving 5% of the precipitate directly in the juice, thus placing the enzym in the presence of the full degree of acidity. Here the retardation was considerable, estimated at nearly one-half, i. e., there was about as much action in fifteen minutes in a water solution as in one-half hour in the tomato juice solution.

Titration of these vegetable juices showed the acidity of the tomato to be +5%, of the carrot +2%, of the radish +0.75%.

THE EFFECT OF OTHER BACTERIAL PRODUCTS.

As a result of his studies on the bacterial soft rot of the turnip due to *Pseudomonas destructans,* Potter (1900: 451) suggested that oxalic acid produced by that organism may play some part in the destruction of the middle lamella and the separation of the cells. The above results show that neither oxalic acid nor any of the normal acids of the host tissues so function in the carrot rot organism. Indeed this organism produces no oxalic acid. It does, however, produce a small amount of some undetermined acid in the presence of carbohydrates. In order fully to determine whether this unknown organic acid or other products of the bacterial metabolism favor or retard the enzym action, broths of various kinds in which the organism has been grown were heated to 80° C. to

sterilize them and to destroy their enzym content. Two parts of each of these, respectively, was then added to one part of a solution in water of the enzym-containing precipitate and the activity of this mixture was tested in comparison with a solution of like strength of the precipitate in pure water. More or less inhibition resulted in every case, as follows: Carrot broth, cultures twelve days old, reaction to litmus slightly alkaline, slight inhibition; beef broth, cultures seven days old, reaction to litmus slightly alkaline, marked inhibition; Dunham's peptone solution, cultures sixteen days old, reaction to litmus neutral, decided inhibition, estimated to be one-half as active as the solution in pure water; Dunham's peptone solution plus 2% sugar, cultures sixteen days old, reaction to litmus strongly acid, decided inhibition, so that the tissues tested in this solution were not more acted upon at the end of twenty hours than were those in the simple Dunham's solution at the end of two hours. There is no evidence here, therefore, that the products of the bacterial growth aid in the cytolytic action of this organism. On the contrary, the evidence is that they tend to inhibit it.

DIASTATIC ACTION.

Repeated trials by the most delicate methods we could devise have failed to reveal any diastatic action worthy of note. The only indication observed has been an extremely slow and slight tendency to the conversion of starch into amylodextrin, as shown by a gradual change in iodine reaction from a clear blue to slightly purplish tint. Starch granules are not eroded even in cultures on potatoes, nor is there any change in the iodine reaction of such raw potato tissues, nor of cooked potatoes when used as a culture medium, except the slight one toward the purplish tint just noted. More delicate tests were made by mixing 1% of the washed starch from potato or wheat flour with water, heating to the boiling point, allowing to settle nearly clear and then filtering off the supernatant liquid. In this way a very weak starch solution was secured, but one which gives a clear iodine reaction. Saliva added to

this solution removes the last trace of starch in a few moments. Equal volumes of this starch solution added to a 5% solution of the enzym-containing alcoholic precipitate from a carrot broth culture of *B. carotovorus* underwent no change even after nine days' standing, other than the slight conversion toward amylodextrin noted above. The enzym-containing alcoholic precipitates from beef broth cultures were likewise inactive. In this respect, again, the carrot-rot organism differs from Potter's white-rot organism of turnip (1901) and agrees with Spieckermann's cabbage rot organism (1902).

Grüss and Reinitzer, as explained in detail later in this paper, have advocated the idea that the cytolytic action of barley malt is simply due to diastase and hold that no "cytase" as distinct from diastase occurs in such extract. Newcombe's work (1899: 81) shows the incorrectness of their conclusions as regards malt extract, and we are convinced from our experiments that in this soft-rot organism we have an enzym different from diastase.

THE ACTION OF THE ENZYM ON THE HOST PLANT TISSUES.

THE COMPOSITION AND ORIGIN OF THE MIDDLE LAMELLA.

Inasmuch as the action of this enzym is chiefly upon the middle lamella of the host cell, it will make the subsequent discussion of this matter clearer if we briefly review the facts as at present understood relating to the composition and origin of this portion of the cell membrane. Fortunately, some excellent work along this line has been done within recent years.[11]

Examination of any mature parenchymatous cell, as of carrot or turnip root, shows the middle lamella as a more or less clearly defined refractive line through the middle plane of the cell walls. On either side, i. e., lying between this and the cell cavity is an inner lamella, or, as Allen calls it, "primary wall." Where three or more cells meet in mature tissue inter-

[11] See critical reviews of the subject by Green (1901: 298–300) and Allen (1902).

cellulars commonly occur and often slits or openings radiate from these for some distance. These result from mechanical strains, doubtless caused by growth changes.

Where such openings occur it is usually evident that the middle lamella substance has split along its middle plane and a brightly refractive border line of this substance bounds each inner lamella externally along these intercellular slits and spaces. In many cases, however, no such intercellular has developed and the middle lamella substance extends as an apparently homogeneous layer of slightly varying thickness between the adjacent inner lamellae of the walls. At the junction of three or more cells this expands into an angular mass, completely filling the space formed by the meeting of their rounded contour lines. As seen in section these masses are most often triangular. There is some evidence from their deeper staining properties that these are denser than the thinner lamellar plates, and our observations on the rate of solution, to be discussed later, are in accord with this idea.

Various opinions have been held as to the composition and origin of the middle and inner lamellae of the walls. It has long been understood that parenchymatous walls of the kind under discussion are composed of cellulose. More recently it has been shown that "cellulose" includes a group of closely related compounds. Moreover, if cellulose stains or solvents be applied to parenchymatous tissues it will appear that the inner lamellae are fundamentally cellulose, whereas the middle lamella does not give the cellulose reactions. More critical observations will show that the inner lamellae are rarely if ever homogenous but also contain substances other than cellulose.

Cross and Bevan (1895:78, 89) in their discussion of celluloses make two groups, (1) the cellulose group, (2) the compound celluloses. They further sub-divide the cellulose group into three sub-groups:

(a) Resistant to hydrolysis, e. g., cotton.

(b) Less resistant to hydrolysis, found in grass stems, etc.

(c) Low resistance to hydrolysis, found especially in fleshy roots and in seeds.

They term groups (a) and (b) the celluloses proper. Group (c) is held to be quite different from these, but for convenience of treatment they allow it to remain in the larger group, accepting Schultze's name as satisfactory, viz., pseudo-cellulose or hemicellulose. As defined more exactly the hemicelluloses are "substances closely resembling in appearance the true celluloses but easily resolved into simpler carbohydrates by the hydrolytic action of enzym or of the dilute acids or alkalies."

We are, however, chiefly concerned with the compound celluloses which Cross and Bevan term "pecto-celluloses," since these constitute the middle lamella and other wall elements acted upon by the carrot-rot enzym. The present understanding of these dates from the work of Fremy (1840, 1848), who found in plant cell walls, along with cellulose, another substance which he called pectose. He also isolated from carrot roots and other plant tissues an enzym "pectase" capable of gelatinizing this pectose and related compounds, which will be discussed in more detail later. Subsequently chemists have confirmed Fremy's observations and conclusions and class the pectose series of compounds with the celluloses as indicated in the discussion above from Cross and Bevan. Mangin has recently (1888–1893) made most extensive studies upon these matters and shows that here again we have not a simple compound but a complex of closely related compounds. These he divides into two natural series, the one neutral, the other acid. Pectose is one of the less soluble neutral series, and pectine is a more soluble form. Both of these are of wide distribution, especially in the walls of young tissues. Of the acid series pectic acid is of common occurrence and peculiar interest to us and especially its insoluble salt calcium pectate. Fremy supposed that when his enzym, pectase, clotted the pectose solutions it did so by converting the pectose into pectic acid. Bertrand and Mallevre (1894, 1895) have recently shown that this clot is, however, calcium pectate. Payen[12] believed that the middle lamella consist largely if not wholly of this salt, and the recent studies of Mangin and Bertrand-Mallevre

[12] Cf. Green 1901: 248.

have confirmed this belief. Moreover, these recent studies have shown that the inner lamellae contain varying proportions of pectose or pectic compounds intermingled with the celluloses. The relation of these is evidenced if Schweitzer's reagent, which is a cellulose solvent, be carefully applied, when it will remove the cellulose and leave the pectic skeleton. The converse occurs, as will be shown in detail later, when the carrot-rot enzym acts upon the walls, removing the pectic elements and leaving the cellulose.

Mangin's studies led him to conclude that in the early stages of its development the wall consists more largely of the less soluble pectose, whereas in the mature wall the calcium pectate predominates in the original plane, i. e., the middle lamella, and the pectose which occurs is in the inner lamellae, i. e., nearer the cytoplasmic layers. The proportion of cellulose becomes increasingly predominant, however, as one passes from the middle to the inner layers. Although this is the case, there probably occurs, even in the young walls, a thin sheet of calcium pectate invisible under the microscope but evidenced by the splitting of the walls along the middle plane under the action of pectate solvents. With the increasing age of the cell this layer is thickened and more clearly defined until it becomes plainly visible in the mature cell as the middle lamella. The splitting of the lamella along the middle lane as a result of the tensions set up between the growing cells indicates that this apparently homogeneous plate is in reality from the beginning a double sheet, one-half of which originated with each daughter cell following mitosis.

Fremy's enzym, pectase, which is especially abundant in growing tissues, is supposed to function[13] in this lamella formation by converting the insoluble neutral pectose of the inner lamellae into the more soluble pectine and ultimately into pectic acid, which then passing, perhaps by diffusion pressure, to the outer surfaces of the inner lamellae, i. e., to the planes where this meets the middle lamella layers, is there combined with calcium to increase this middle lamella substance. This appears homogeneous, but as will appear later is, like the

[13] Cf. Green. 1901: 297–300.

inner lamella, distinctly stratified in structure, at least in the heavier parts at the angles.

This conception involves the idea of the passage in the growing walls of the pectose substances by gradual filtration through the cellulose layers from the protoplast where they originate toward the exterior, and is at the same time in accord with the idea of Allen (1902: 31) that the young cambium wall really forms the basis of the middle lamella of the older tissues.

THE ACTION OF THE ENZYM ON THE CELL-WALL.

The rapidity of the invasion of vegetable tissues by the carrot rot organism was discussed in our earlier report (1900 :307–312). As there explained it rots only parenchymatous tissues. The invaded tissues become watery and usually more or less darkened in color when exposed to the air. The cells rapidly lose all coherence and always show a sharply defined line of demarkation, indicating that the softening occurs quickly and completely after it begins. Examination of such recently decomposed tissues under the microscope shows the cells to be already isolated or easily separable along the plane of the middle lamella. The protoplasmic sac within the cell is collapsed, more coarsely granulated than normally, and evidently dead and in the process of disorganization. Bacteria teem around and between these cells but are so rarely seen within them that where this does occasionally occur, one is led to attribute it to mechanical rupture of the softened walls rather than to direct solution. (See figures 1, 5 and 6.)

In the case of the inoculation of a cut surface of root kept in ordinarily dry atmosphere, the invaded area dries out very rapidly; if, however, it is kept in a saturated atmosphere gray drops of exudate teeming with bacteria form on the surface and the tissues underneath become sunken. It is evident, therefore, that among the products of the bacterial growth are active osmotic substances which draw the water, and of course soluble nutritive matters, from the dying or dead protoplasts. The organism is powerless to invade wilting or pithy and partially dried-out vegetable tissues of even the most susceptible

varities, such as turnip, radish and carrot. These facts, with others to be set forth later, show its active invasion to occur in the intercellular spaces and along the planes of the middle lamellae. A fundamental condition of this invasion is an abundant moisture content in the host tissues, the more the better, apparently. The water-logged, or translucent appearance of the invaded tissues is doubtless due in part to the expulsion of gas incident to the filling of the intercellulars with liquid resulting from the plasmolysis of the cells, and in part to the changes in the optical characters of the walls themselves. The fresh walls are uniformly refractive throughout with a slight difference between the middle and the inner lamellae. Almost immediately following their immersion in either a living culture or an aqueous solution of the precipitated enzym the inner lamellae begin to lose their refractiveness. This change in appearance is evident even to the unaided eye if thin sections are closely observed. It is more rapidly followed under the microscope, and is then seen to be associated with a swelling of the primary wall or inner lamellae, sometimes to twice their original thickness, and with the appearance within a short time of a delicate laminated structure in these swollen walls, as shown in the accompanying figures. The middle

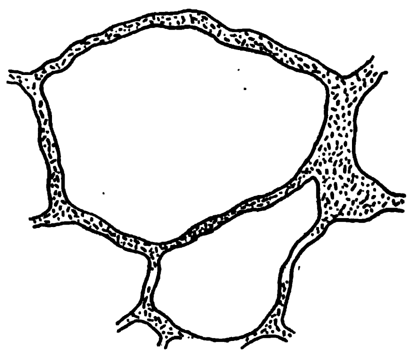

FIG. 5. A sterile block cut from living carrot root was immersed for 20 hours in a broth culture of *B. carotovorus*, then fixed in hot absolute alcohol, imbedded in paraffin and sectioned. The above sketch (x 250) shows a large thin-walled parenchyma cell lying about three cells inward from the surface. The enzymic action was here complete, the cells isolated and the intercellular spaces gorged with bacteria, but the undissolved remnant of the wall kept them from invading the cell cavities.

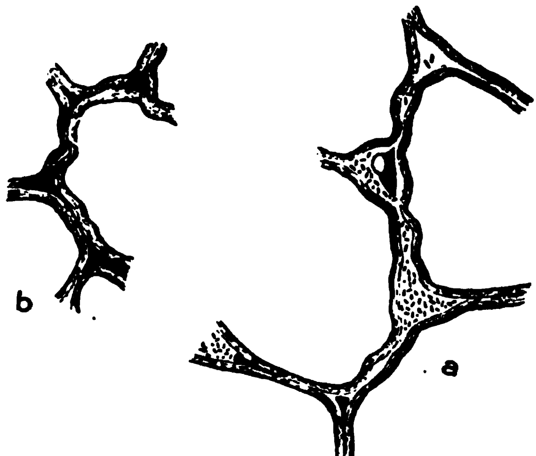

FIG. 6. From deeper lying portions of the same sections as Fig. 5. (x 375). The cells here were smaller and thicker walled. In a, the bacteria were abundant in the intercellulars and the middle lamellae partly dissolved; b, from a little deeper, showed less advanced action, the walls swollen and laminated but still cohering.

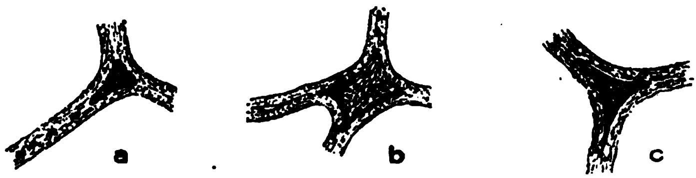

FIG. 7. Cell mebrances from the central part of the same sections (x 500). The earliest stages of bacterial invasion along the plane of the middle lamellae are shown in a and b, while c shows the action upon the walls in advance of invasion. The laminated structure appears both in the swollen inner lamellae and in the undissolved portions of the middle lamellae which occur at the angles of the cells.

lamellae also becomes less refractive, though not softly translucent, as do these adjacent inner layers, and soon begin to melt away in the thinner portions. The middle lamellar substances, as already explained, usually form thicker masses at the angles of the cells, often triangular as seen in optical section. As the thinner parts dissolve, these heavier portions remain isolated. There are now distinct openings between the adjacent cells in most places and the swelling of the walls has reached its maximum. Tapping on the cover glass, tearing with needle point or other mechanical test, will show that

the cells have lost all cohesion, that is, that the tissues are fully "rotten." Thin razor sections of carrot or turnip placed in living cultures or in active enzym solution pass through these changes in from ten minutes to an hour, although longer immersion may be necessary to secure the complete solution of the thickest pieces of intercellular substance. Meanwhile there is a slight thinning of the walls proper from without inwards, i. e., from the lamellar side towards the cell cavity, but this is not great and complete solution has never been observed either in the presence of the living organisms or in solutions of the enzym. In order to determine this matter to our satisfaction the same sections have been kept under observation for three weeks, with repeated measurements and camera drawings during this period, but there was little change after the first few hours. Cellulose stains (iodine and sulphuric acid or chlor-zinc-iodine) give clear blue reactions with these fully softened walls, and this reaction is the same even after the longest immersion. The lamination of the walls becomes increasingly apparent for a short time, after which there is no further change.

In no case have we found evidence of any action whatsoever upon lignified or cuticularized walls. Vessels lie for days or weeks in the presence of the enzym with the walls unchanged in refractive character or other appearance or in staining reaction to phloroglucin.

In order to follow the course of invasion more carefully blocks of fresh carrot tissue cut from near the core, with precautions to insure sterility, have been immersed in broth culture tubes of *B. carotovorus* and at varying periods of time after the surface tissues had begun to show decomposition they have been carefully transferred to absolute alcohol to kill and fix the organisms in place, then imbedded in paraffin and sections cut three to twelve microns in thickness. For differentiating the wall tissues and organisms various stains have been tried, including Ziehl's carbol-fuchsin and aqueous solutions of Congo red, ruthenium red and methylene blue.

The best results were obtained from the use of ruthenium red and methylene blue. It was found that about two minutes'

immersion in each of these in turn, followed by brief washing in alcohol, gave slides showing excellent differential staining. The organisms, the unaltered walls and the undissolved remains of the middle lamellae retained the blue color and in the walls which had been fully acted upon the red color predominated. Examinations of slides so stained have shown very interesting conditions. The Congo red also clearly reveals the solvent action, staining deeply the unaltered walls and giving but faint color to those from which the soluble part has been removed. The line of demarkation between such deep and faint staining tissue is very abrupt, indicating that the solvent action is rapid and complete after the penetration of the active substance. This action occurs some ten cells, more or less, in advance of the invasion of the organism. It is evident that the chemical agent causing this change penetrates the tissues and completes its action considerably in advance of the invasion of the organism. The rate of the invasion was clearly dependent upon the nature of the walls and the form of the cells. As already stated, no action occurs on cuticularized or lignified walls. Where the cells were much elongated in one direction the action progressed more rapidly in the direction of their longer axis. The organisms in the more recently invaded portions were chiefly found in the larger intercellular spaces at the angles of the cells. From these they made their way, evidently along the planes of the dissolved lamellae, occurring in the narrower portions as a single line of rods lying end to end. In no case were they within the cell cavities, although they often crowded the lumina of the open vessels. The walls themselves showed in these stained sections the same transitions noted in the fresh material, viz., swelling, and evident lamination of the inner lamellae preceding the full solution of the middle lamella. The middle lamellar substance itself, especially at the angles of the cells where it occurred in larger masses, showed distinctly a laminated or fibrillar structure when partially acted upon, indicating that it, like the wall, is not of entirely homogeneous structure.

The discussion thus far has been based upon observations made upon carrot tissues. Studies of the invasion of turnip

and radish roots and cabbage petioles have shown practically similar conditions. The rate of softening of sections of these tissues in solutions of the enzym-containing precipitate and in living cultures has proved to be more rapid in the turnip, radish and cabbage tissues than in those of the carrot. In the latter the action was faster on the core than on the cortex tissues. It was more rapid in the young potato than in the mature tuber. On the beet root no action whatever occurred.

In order to secure data for the above conclusions careful trials were made on two occasions with a 5% solution of an alcoholic precipitate containing a not very active enzym. This weaker enzym, acting more slowly, permitted more satisfactory differentiation between the rate of softening of tissue of similar susceptibilty. The trials were made about July, using vegetables fresh from the garden except for the potatoes of Series I. The details are as follows:

Series I. Using thick razor sections of (1) old potato, core; (2) young carrot, a. core, b. cortex; (3) young radish, core; (4) young turnip, core; (5) cross sections of young cabbage petiole. The interval before complete disintegration was: turnip, forty minutes; radish and cabbage, about forty-five minutes; carrot core, eighty minutes; carrot cortex, ninety minutes; potato, one hundred minutes.

Series II. Using similar solutions and vegetable sections, except that sections from a young potato tuber fresh from the garden were substituted for the old potato (1), and the following were added : (6) cotyledon of pea, approaching maturity; (7) root of beet. The intervals before complete disintegration were turnip, radish, cabbage (about alike), thirty-five minutes; young potato, carrot core (about alike), eighty minutes; carrot cortex, pea (about alike), one hundred minutes; beet, limp but no signs of disintegration even after twenty-four hours' immersion.

These observations as to the rate of action of the enzym on plant tissues clearly accord with the results from inoculations into the corresponding vegetables made in our earlier studies (1900:307) and indicate, what we would expect, that aside from moisture relations the relative susceptibility or resistance of the host plants to infection depends largely, if not wholly, upon the composition of the middle lamellae.

A COMPARISON OF THE ENZYM PRODUCED BY BACILLUS CAROTOVORUS, WITH CYTOLYTIC ENZYMS FROM OTHER SOURCES.

CYTOLYTIC ACTION BY SOFT-ROT BACTERIA FROM OTHER SOURCES.

In the course of these studies upon the cytolytic enzym of the carrot-rot bacillus comparisons have been made with the various other strains of soft rot organisms described in Part I of this discussion, p. 100. In order to make this clear we will summarize the list, which includes 45 strains, as follows:

Three strains of cabbage-rot bacilli isolated in Vermont by F. R. Pember in 1899.

Twenty-three other strains of cabbage-rot bacilli isolated in Vermont by W. J. Morse in 1901.

One strain of turnip-rot bacillus isolated by L. P. Sprague in Vermont, 1903.

Twelve strains of soft-rot bacilli secured by Harding and Stewart in New York, of which one was associated with the soft rot of *Amorphophallus simlense* and the other eleven were from the soft rot of cabbage.

Six other soft-rot organisms from various sources, as follows: Townsend's calla rot, *Bacillus aroideae;* Harrison's cauliflower rot, *Bacillus oleraceae;* van Hall's two iris-rot organisms, *Bacillus omnivorous* and *Pseudomonas iridis;* Spieckermann's kale-rot organism (*Bacillus*), and Potter's turnip-rot organism, of which the strain we had was also a *Bacillus.*

Forty of these forty-five strains, with three others, were studied* in detail by Messrs. Harding and Morse, the details of their studies being related in Part I of this discussion. It will

* Their studies did not include the following: Pember's R., *Pseudomonas iridis*, nor the New York organisms O. 1 II 6 c, O. 1 II 6 a, and the bacillus from Amorphophallus.

suffice here to say that their comparative studies as there recorded lead them to conclude (p. 133) that these forty strains probably constitute only one somewhat variable species. The following comparisons as to enzym production were, however, completed before their decision was reached and we believe they were worth recording partly as contributing further evidence as to the general likeness of these strains and partly as emphasizing the minor variations which we believe must always be expected to occur with different bacterial strains, even of the same (so-called) species.

The comparisons as to enzym production have been made by testing both the living cultures and the alcoholic precipitates, following the general methods outlined earlier in this article. Inasmuch as the alcoholic precipitate yields the enzym in a more concentrated form, and one in which it can be preserved indefinitely for comparative trials, this method has been chiefly relied upon. In all cases much care has been exercised to insure uniformity in the several series as to medium and cultural conditions. The trials of cytolytic activity were made on razor sections of vegetables, carefully selected for uniformity, and the trials repeated until convincing evidence was obtained as to relative activity. Inasmuch as it was not practicable, for obvious reasons, to make close comparison of more than a limited number of these at a time, they were handled in series of six or eight in a group. Since there was some variation in the vegetable upon which the test was made in different cases it is to be noted that *B. carotovorus* of the original strain, or some other organism whose activity was well known, was included in each series. In all cases except Pember's organism R. cytolytic action occurred. In order to have a basis for comparison the organisms of each series were grouped in order of cytolytic activity into three classes, as follows:

Class I. Activity moderate, *B. carotovorus* being the standard of his class.

Class II. More active than I, intermediate between I and III.

Class III. Most active, Vermont XLVIII and Turnip Rot D well representing this class.

The following tables give the results of the trials grouping the various organisms in these classes according to cytolytic activity.

SERIES I. EIGHT DAYS' GROWTH; CULTURAL CHARACTERS ALIKE IN ALL; CYTOLYTIC ACTION TESTED ON CARROT AND CABBAGE.

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
Calla rot (B. aroideae)[14]	1%	.465 gr.	111.	0.
Pember A	1%	.254 "	111.	
" R	1%	.532 "	0.	
Vermont XXXIII	1%	.344 "	11.	
" XLVIII	1%	.370 "	111.	
B. carotovorus	1%	.467 "	1.	0.

[14] In some other trials Calla rot has proved about like *B. carotovorus* in enzymic activity.

SERIES II. NINE DAYS' GROWTH; CULTURAL CHARACTERS ALIKE IN ALL; CYTOLYTIC ACTION TESTED ON RADISH.

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
Pember A	1.1%	.355 gr.	111.	0.
Vermont XLVIII	1.4%	.374 "	11.	0.
" LI	1.3%	.391 "	1.	0.
" LIV	1.4%	.393 "	11.	0.
" LVI	1.2%	.434 "	1.	0.
" XCIV	1.3%	.366 "	1.	0.
" XCVII	1.1%	.293 "	111.	0.
" CII	1.4%	.260 "	11.	0.

SERIES III. SEVEN DAYS' GROWTH; CULTURAL CHARACTERS ALIKE IN ALL; EXCEPT THAT MORSE'S 98 SHOWED LESS AND PEMBER'S 2 HEAVIER CLOUDING THAN THE REST; CYTOLYTIC ACTION TESTED ON RADISH AND TURNIP.

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
Vermont XXV	1.%	.300 gr.	11.	0.
" XXIX	1.%	.241 "	11.	0.
" XXXI	1.1%	.241 "	1.	0.
" XXXIII	0.7%	.344 "	11.	0.
" XCVIII	0.9%	.275 "	11.	0.
" CIII	1.%	.185 "	11.	0.
Pember C	0.8%	.366 "	111.	0.
" R	1.3%	.350 "	0.	0.

SERIES IV. SEVEN DAYS' GROWTH; CULTURAL CHARACTERS ALIKE IN ALL; CYTOLYTIC ACTIVITY TESTED ON TURNIP AND RADISH.

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
Vermont XLVIII	1.1%	0.315 gr.	111.	0.
" XLIX	1.2%	0.335 "	11.	0.
" L	0.8%	0.386 "	11.	0.
" LII	0.4%	0.230 "	111.	0.
" LV	1.%	0.317 "	1.	0.
" XCV	2.%	0.304 "	111.	0.
" XCVI	1.2%	0.300 "	11.	0.
" XXVI	1.2%	0.303 "	11.	0.

SERIES V. SEVEN DAYS' GROWTH; CULTURAL CHARACTERS ALIKE IN ALL; CYTOLYTIC ACTIVITY TESTED ON TURNIP AND RADISH. (VERMONT XLVIII FROM SERIES IV WAS INCLUDED IN HERE AS A CONTROL.)

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
Vermont C	1.3%	0.334 gr.	11.	0.
" CI	1.2%	0.238 "	111.	0.
New York, 0.2 e	1.2%	0.410 "	1.	0.
" Miller, 3 No. 2	0.9%	0.380 "	111.	0.
" 0. R. Be	0.1%	0.334 "	1.	0.
" Miller 2, No. 2	0.9%	0.252 "	11.	0.
" 0. R. Bl	1.2%	0.400 "	111.	0.
" 0. 1 II 6 c	1.%	0.440 "	11.	0.
Vermont XLVIII	1.1%	0.315 "	111.	0.

SERIES VI. SEVEN DAYS' GROWTH; CULTURAL CHARACTERS ALIKE EXCEPT GENEVA 10 WHICH SHOWED HEAVIER CLOUDING AND PELLICLE; ENZYMIC ACTIVITY TESTED ON TURNIP AND RADISH.

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
New York, Miller 3, 3	1.3%	0.361 gr.	1.	0.
" Miller, 3, 1	1.5%	0.240 "	11.	0.
" Riverhead 3, 1	1.7%	0.250 "	11.	0.
" 0.1 II 6a	1.3%	0.134 "	1.	0.
" 0.2 f	1.5%	0.264 "	111.	0.
" Riverhead 2, 1	1.8%	0.237 "	11.	0.
Vermont XLVIII	1.5%	0.258 "	111.	0.

SERIES VII. SEVEN DAYS' GROWTH; CULTURES SIMILAR IN VIGOR AND GENERAL APPEARANCE; TESTED ON TURNIP.

Organism.	Reaction.	Weight of Precipitate.	Cytolytic activity.	Diastatic activity.
B. carotovorus	1.4%	0.689 gr.	1.	0.
Kale rot (Spieckermann)	2.%	0.626 "	111.	0.
Turnip Rot D	1.8%	0.674 "	111.	0.
B. olereaceae	1.7%	0.350 "	1.	0.
B. omnivorus	1.8%	0.435 "	11.	0.
Potter's bacillus	2.%	0.676 "	11.	0.

These results are in general accord with those of preceding investigators so far as published.

Potter describes (1899, 1900) for his *Pseudomonas destructans* action upon the wall like that we have observed for *B. carotovorus*. He records later (1902: 393) evidence of direct penetration of the softened cellulose remnant of the wall by the organism. This is probably to be regarded as due to physical pressure rather than to solution of membrane, though

it is so interesting and important a thing that it is to be hoped that further confirmatory evidence may be adduced. Potter also records diastatic action by this organism. In comparing our results with his it is to be borne in mind that the organism we have in culture is probably not his original organism, since this is a *Bacillus* instead of a *Psuedomonas.*

Spieckermann (1902) describes in detail cytolytic action by his organism identical with that observed by us, and absence of diastatic action.

Van Hall (1903) likewise describes in detail cytolytic action stopping short of complete solution of the cellulose wall and absence of diastase action by *Bacillus omnivorus.*

Harrison (1902) has attributed solution of the middle lamella to the organisms described by him.

We are therefore convinced that in all of these cases, including the forty-five strains of organisms from different sources, there is developed the same middle-lamella-dissolving enzym as in *B. carotovorus,* and that moreover in all cases alike there is neither complete solution of the cellulose elements of the wall nor diastatic action.

CYTOLYTIC ACTION AS RECORDED FOR OTHER BACTERIA.

The fact that the softening and solution of plant cell walls result from certain bacterial growths has been known for many years.

Mitscherlich in 1850 observed the destruction of cell walls and consequent liberation of starch when potatoes decompose in water, and believed it due to the vibriones which develop in the liquid.

Van Tieghem (1879) studied the decomposition of various vegetable tissues. He considered this due to the action of a single polymorphous species of *Bacillus* to which he gave the specific name *amylobacter.* He found that these organisms could decompose only the younger or less resistant tissues. Old tissues and those lignified, cuticularized, or suberized were resistant to the action as also was the cellulose of bast fibres.

De Bary (1887: 101) accepted van Tieghem's account of the breaking up of cellulose membranes by a "diastatic enzym" in the process of decay attributed to *Bacillus amylobacter*. It is, however, generally agreed by bacteriologists to-day that this name is applicable to a class of bacteria rather than to any single species.

Vignal (1889) in his monograph on *Bacillus mesentericus vulgatus* records that it secretes a ferment capable of dissociating the cells of potato tubers by dissolving the intercellular substance, i. e., middle lamella, but without dissolving the cellulose of the wall. Similar action occurred upon parenchymatous tissues of beans, chestnuts, turnip, carrot, cabbage, beets and numerous young stems when these were immersed in the cultures. In none of these did full solution of the cellulose walls occur even after three months. It is noteworthy that this organism at the same time developed several other enzyms, viz., diastase, a proteolytic enzym, and a rennet, and that the cellulose remnant of the wall persisted in the presence of all of these.

Heinz (1889) observed a similar disorganization of the tissues of hyacinth as a result of the invasion of the tissues by the organism he describes as *Bacillus hyacinthus septicus*. It is noteworthy that he found this organism incapable of liquefying gelatin, in which it differs from the carrot-rot organism.

Van Senus (1890) observed the solution of fibrous and parenchymatous plant tissues by bacteria. He attributes the action to *B. amylobacter* and a smaller kind acting conjointly, neither alone accomplishing it. His methods have been considered by later investigators too crude to insure reliable results.[15]

Kramer (1891) isolated from decaying potatoes an aerobic spore-forming bacillus capable of dissolving the intercellular substance of potato tissue, and of attacking the cellulose membrane also.

Frank (1899) found dissociation of the cells of potato as a result of the invasion of *Micrococcus phytophthorus*. The action of this organism likewise stopped short of the solution

[15] Cf. Omelianski, 1902: 200.

of the cellulose layers, removing only the middle lamella, and also left the starch grains intact.

Wehmer (1898) studied the bacteria concerned with the rotting of potatoes, all of which he regarded as of saprophytic nature. He found two types of decomposition to occur, associated with different organisms. In the first, "breifäule," the middle lamellae only are dissolved. He considers that the acid produced by bacteria may be the agent in this solution of the pectic componds, rather than an enzym. In the second, "schleimfäule," there is ultimately solution of the entire wall substance.

Laurent (1899) working with *Bacillus coli communis* found that, although normally a saphrophyte as concerns plant tissues, yet when inoculated into weakened vegetables it developed there and in so doing acquired virulence as a parasite upon potatoes of full vigor, and also upon turnip and onion. There was no secretion of diastase (amylase). Heating the culture to 62° C. for five minutes destroyed this ferment.

Lepoutre (1902), continuing Laurent's work by similar methods, developed strains pathogenic to plant tissues of three other species of bacteria, normally saprophytic, viz., *Bacillus fluorescens liquefaciens*, *B. mycoides* and *B. mesentericus.* The first acted like *B. coli communis* in Laurent's cultures, viz., dissolved the middle lamella, but not the cellulose or the starch. Lepoutre considered the solution of the lamella due to an enzym which he speaks of as a variety of pectinase, evidently accepting the name suggested by Bourquelot and Herissey (see discussion later in this paper).

Migula (1900:529) states that the culture of his *Bacillus asterosporus* upon slices of cooked carrot leads to the solution of the middle lamella.

Winogradsky (1895) studied the retting process of flax and considered it due to a single specific anaerobic bacillus. He concluded that this fermented the pectin elements readily but was without influence on cellulose proper, e. g., Swedish filter paper. This conclusion is in accord with the opinion expressed by Kolb (1868) that the retting process is essentially a pectic fermentation.

Behrens (1902) studied further the organisms concerned with the different methods of flax retting. He found that in all cases alike the essential thing is the solution of the middle lamellae of the parenchyma cells. He concluded that in the latter process a specific anaerobic bacillus is the agent, while in other processes fungi (Mucors) take the active part.

Haumann (1902) studied the flora of retting flax and concluded that there are numerous species of bacteria and fungi active in the process. He found several of these species capable of liquefying calcium pectate.

Doubtless further search would reveal other records of the solution of the middle lamella without evidence of the solution of the cellulose layers. It may safely be inferred, in our judgment, that the action in most of these cases was like that in the soft-rot organisms studied in our laboratory. These citations will at least suffice to emphasize the point that such action on middle lamellae apart from action on cellulose is a common occurrence in bacterial fermentation. It must not be concluded, however, that cytolytic action by bacteria is confined to the middle lamella and like parts of the wall. While this is the action concerning which we have the most detailed evidence, proof is not lacking that there are bacteria capable of causing the full solution of parenchyma walls, and even of the more resistant cellulose of fibre.

E. F. Smith (1903) has shown this in his painstaking work upon the black rot of the cabbage caused by *Pseudomonas campestris*.

No other equally convincing evidence has come to our attention as to like action by bacteria parasitic upon plants. We have no doubt, however, that such cases will be found not infrequently as bacterial plant diseases are more fully investigated.

Omelianski (1895) began in 1894 a study of the solution of normal or typical cellulose as represented by Swedish filter paper. The final summation (1902) of his painstaking work shows that at least two species of bacteria are capable of causing the complete solution of this most resistant cellulose. He

believes that further study will reveal other such organisms. He considers that in the so-called "cellulose-fermentation," earlier writers were dealing chiefly or wholly with the more easily hydrolyzable celluloses and pectic compounds.

CYTOLYTIC ACTION OF CERTAIN FUNGI.

Although it has long been known that fungi penetrate cell walls, de Bary (1886) first separated a cytolytic enzym from the living fungus and studied its characters and action. He thus proved that *Peziza sclerotiorum* (*Sclerotina libertiana*) secretes a soluble ferment which causes some swelling of the walls of vegetables invaded by it, followed by a solution of the middle lamella and consequent isolation of the cells. He observed a partial solution of the inner lamellae, and the residual portion gave a beautiful cellulose reaction with chlor-zinc-iodide.

Ward two years later (1888) did his painstaking work on the lily *Botrytis*. Here he found an enzym which causes a swelling and laminations of the inner and solution of the middle lamella of the cell walls of the host plant. He considered it "extremely probable this ferment is of the same nature as the one extracted by de Bary." Ward also observed the extension of cytolytic enzym drops from the tips of the *Botrytis* hyphae, which he considered to be associated with the hyphal growth.

Arthur (1897: 499) records similar lateral exudations upon the young hyphae of *Rhizopus*, which he believes to be associated with the local secretion of cytohydrolytic enzym.

Laurent (1899) in subsequent studies upon the *Sclerotinia* enzym found it to be destroyed by heating to 54° C. when in solution, whereas it required 62° C. to destroy the middle lamella dissolving enzym of *Bacillus coli communis*. He concludes from this that these enzyms must be different. His argument is less convincing from the fact that his two enzyms were secured from cultures made on different vegetable media, viz., artichoke in one case and potato in the other. There may have been by-products from the *Sclerotinia* culture which lowered its resistance. The fact was referred to, earlier in this paper, that Green (1901:448) and others have recorded much

wider differences, under varying conditions, in the thermal destruction point of certain other enzyms. This must at least make one cautious in accepting conclusions drawn from such evidence.

Kissling (1889) studied the pathogenic action of *Botrytis cinerea* and found that it formed a poison which kills the protoplasm of the invaded tissues, and which he thought enzymic and the same as the ferment secured by de Bary from Peziza. Kissling did not, however, differentiate between the two changes which occur, viz., the death of the protoplasm and the dissociation of the cells.

Kean (1890) showed that the decay of sweet potatoes and other vegetables as a result of the invasion of *Rhizopus nigricans* (*Mucor stolonifer*) is due to an enzym which softens the tissues, but he does not give the details of the changes as secured under the microscope. He found a similar softening by the juice expressed from potato leaves infested with *Phytophthora infestans*, also from a *Botrytis* growing on stone crop (*Sedum*).

Miyoshi (1895) observed the penetration of the walls of different plants by *Botrytis* and *Penicillium* and inferred the presence of an enzym, but did not isolate it.

Behrens (1898) published the results of his extensive studies upon the pathogenic action of *Botrytis vulgaris* (*B. cinerea*)[16] upon fruits and clearly distinguished between the toxic and cytolytic action. He showed that there is a toxin developed which is not destroyed by boiling, thus confirming de Bary's observations, and in addition an enzym or enzyms which acted like de Bary's in causing dissociation of the cells. He found enzymic action from *Penicillium glaucum* and *P. luteum*, but only upon the middle lamella. In order to determine the relation to cellulose and calcium pectate respectively he grew these fungi for forty-eight days on culture fluids containing Swedish filter paper. He found that *Botrytis* reduced the total solids whereas these increased with the other two. He concludes that *Botrytis* is capable of dissolving cellulose, probably

[16] Smith, R. E., shows these names to be synonyms.

converting it into dextrine, whereas the others are not. He then cultivated all three upon a synthetic medium containing 1% calcium pectate. He found that these fungi grew better upon this than upon a similar medium containing arabinose instead of the pectate. On the other hand *Oidium fructigenum* did better on the arabinose medium. This result accorded with his later observations that the first three dissolve the middle lamella of host plants by enzymic secretions, whereas the *Oidium* cannot, but makes its way wholly by mechanical pressure. He is of the opinion that the enzym of *Penicillium*, which dissolves the middle lamella but not the cellulose, is different from the cellulose-dissolving enzym.

Nordhausen (1899) at about the same time made, independently, similar studies upon *Botrytis cinerea* and reached very nearly the same conclusions. He emphasizes the fact that this *Botrytis* differs somewhat in its action from Ward's lily fungus in that the enzymic solution of the middle lamella is not accompanied as a rule by the strong swelling of the inner or cellulose layers. In this respect the action is more like that of de Bary's *Sclerotinia*. He considered the swelling observed by Behrens, of the cell walls of *Symphoricarpus*, an exceptional thing for this fungus.

R. E. Smith, in a recent paper (1902) on *Botrytis cinerea*, reports that while it dissolves the middle lamella of lettuce parenchyma it causes no swelling of the residual layers. Moreover, he found the action occurred even after the fungus extract causing it had been heated to the boiling point. He considered that this action is probably identical with that of de Bary's Peziza, but that in Ward's lily fungus and Potter's turnip bacterium an enzym was produced different from any ordinarily produced by *Botrytis cinerea*. He emphasizes the importance of the rôle of oxalic acid, which is formed by this fungus and also by de Bary's.

Grüss attributed the cytolytic action of *Penicillium* to diastase. He applied the name alloölysis to such action in which the enzym evidently penetrates the substance and the solution is preceded by visible changes, forming a "corrosion zone," as

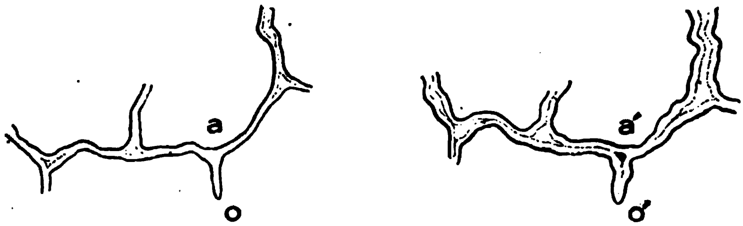

FIG. 8. Camera drawings of margin of a very thin section of carrot root tissue; a, normal, a', same 13 minutes after immersion in 5 per cent. solution of enzymic precipitate of *B. carotovorus*. (See also Fig. 4 where same solution was used.) Since the projecting wall fragment at 0' was most fully exposed to the cytohydrolytic action it was carefully measured to determine whether it would undergo any shortening. The enzym solution was renewed, with the addition of chloroform to inhibit bacteria, and the slide kept under observation for three weeks, but no further solution occurred.

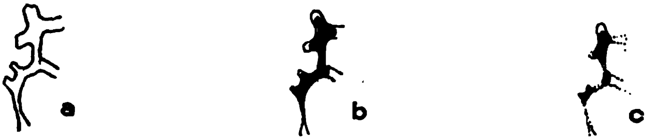

FIG. 9. Similar camera drawings of a bit of the cell wall projecting from the margin of a thin section of carrot-root tissue. The normal wall is shown in a; b, the same after 20 minutes action of 2.5 per cent. aqueous solution of taka diastase; c, after 22 hours action, showing the gradual solution of all parts, the middle lamella being more persistent.

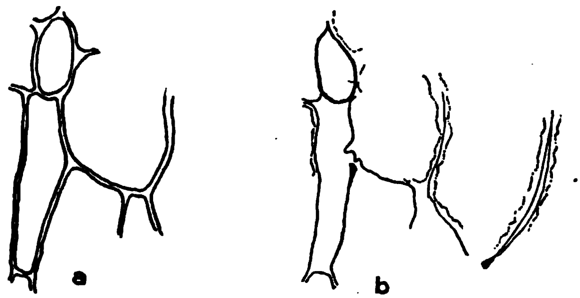

FIG. 10. Similar drawings from another preparation; normal carrot walls shown in a; b, the same after 2 hours action of 2 per cent. solution of taka diastase. The continuous lines show the more persistent middle lamellae. The innner lamellae were entirely dissolved in places.

contrasted with the surface erosion ("Abschmelzung") of starch grains by diastase.[17]

Newcombe (1899) published the results of studies upon the commercial preparation, "taka-diastase," which is the enzym-containing precipitate from the fungus *Aspergillus oryzae.* His tests upon barley endosperm sections showed a cytolytic action. The walls became hyaline, first near the middle, this change then progressing through the inner lamellae toward the cell lumina. Following this, these wholly hyaline walls (inner lamellae) began to disappear from the borders (cell lumina) toward the middle of the wall so that a faint and thin middle lamella often persisted for forty-eight hours after the beginning of the experiment. A similar melting away of the walls of the aleurone layer occurred more slowly. Newcombe also studied its action on the cell walls of the cotyledon of *Lupinus albus* with like results, the middle lamella again proving more resistant to this enzym than did the inner lamellae.

We have repeated Newcombe's work and found the results as he describes. Trial was then made of taka-diastase in comparison with the enzym from *B. carotovorus* on carrot-root walls. The results are shown in the accompanying figures 8–10.

THE CYTOLYTIC ACTION OF POLLEN-TUBES.

Elfving (1879) and Strasburger (1884) have studied the development of pollen tubes and found that in general they burrow through the plane of the middle lamella, thus passing between the cells rather than through them.

Miyoshi (1894) found the tubes capable in some cases at least of actually penetrating the walls. Both Miyoshi and Green (1894) conclude that the action of pollen tubes is such that the secretion of a cytolytic enzym must be inferred. Green made a series of careful experiments with pollen both before germination and during the process planned to demonstrate the presence of this and other enzyms which he judged to be present. He secured inulase and diastase but was unable to

[17] See abstract of Grüss article. *Centralbl. f. Bakt.* **II 2: 585 (1896).**

get evidence of cytolytic action from the extracts of any pollen he tested.

No later trials have come to our attention and we are therefore unable to go further than to make inferences as to the presence of a cytolytic enzym in pollen. Green concludes that it is there in spite of his failure to secure it and that it is similar to the lamella-dissolving enzym of Ward's lily *Botrytis.* The penetration of the walls observed by Miyoshi may easily have resulted from mechanical pressure without the complete absorption of the cellulose layers of the walls.

CYTOLYTIC ACTION IN SEEDS AND OTHER STORAGE TISSUES OF THE HIGHER PLANTS.

The endosperm of seeds has the cell membranes characteristically of the easily-hydrolyzed or hemicellulose type, and the same is true of other plant storage tissues such as fleshly roots and tubers. The solution of these in the normal processes of germination or growth-resumption has long interested plant physiologists.

Sachs (1862) observed the solution of the endosperm of the date palm, *Phoenix.* This was attributed to an enzym, but attempts at isolation of a soluble ferment from the seeds of another palm, *Livistonia,* by Green (1893 : 94) failed and it remained for Newcombe (1899 : 67) to secure the cytolytic enzym from germinating seeds of *Phoenix dactylifera.*

The first enzym of this class isolated from seeds was, however, obtained by Brown and Morris (1890) from barley malt. They found that the alcoholic precipitate of malt extract contained a cytolytic enzym in addition to diastase. This functions, during normal germination, leading to the solution of the endosperm walls preceding the solution of the starch granules by the diastase. The details are of interest: First, a slight swelling of the inner lamellar walls, bringing out evidence of stratification; second, the gradual solution of the modified inner lamellae, the middle lamella being the most resistant; third, the solution of the middle lamella. Newcombe (1899 . 52) repeated and confirmed their observations later and

states that the inner lamella was dissolved down to the middle lamella within five to fifteen hours, whereas the latter persisted for from one to ten days before complete solution.

Brown and Morris (1890 : 500), testing the barley enzym on other tissues, found potato sections rapidly decomposed. It was found that the cell walls swelled, became differentiated into very thin laminae which later broke up into spindle-shaped fragments and ultimately disappeared with the exception of a thin layer representing the middle lamella. The artichoke, carrot and turnip behaved like the potato, but beets and apples were affected little or not at all. Heating to 60° C. rendered the enzymic solutions inactive on the walls, whereas this diastatic action withstood 70°.

Brown (1892) has since found a like enzym in oats and rye and reached the conclusion that the cytolytic action which occurs in the early stages of the digestion of these grains by animals is due to the action of the ferment present in the grains themselves rather than to the digestive juices of the animal.

Gardiner (1897 :106) observed solution of the walls in the endosperm of *Tamus communis* during germination. The disorganization of the walls was accomplished by marked stratification and the middle lamella was dissolved first, the inner lamellae later.

Grüss (1896) in working upon germinating barley, observed the same changes as Brown and Morris, and applies the name "alloöysis" to the behavior. His use of the term was explained earlier in the article. He speaks of four sorts of "diastase" which may be differentiated in germinating barley, (1) translocation diastase, (2) secretion diastase, (3) glukase, (3) cytase. He holds that the last of these "must yet be held as questionable," concluding that "secretion diastase" may cause the cytolytic action and may be more and more weakened by heating above 50° C., so that it loses the power previously possessed of acting on saccharo-colloids. It is of interest to note that Grüss' use of the word "cytase" in the above connection marks the origin of this word so far as we have learned.

Reinitzer (1897) likewise refused to admit that the cytolytic action in barley is due to another ensym that diastase although he considers that an enzym, cytase, differing from the barley enzym may occur in seeds having the walls thickened with hemicellulose as a reserve material.

Bourquelot and Herissey (1898) made trial of the enzymic action of a barley malt extract, secured by the method of alcoholic precipitation, upon a solution of pectine from gentian. They found evidence of the presence of an enzym, destroyed by heating to the boiling point, which was capable of so changing pectine that it cannot thereafter be gelatinized by the action of the clotting enzym, pectase. This is, they believe, due to the conversion of the pectine into reducing sugars. For this enzym they propose the name pectinase.

Green (1901 : 104) considers that they did not prove this "pectinase" to be different from the cytolytic enzym of Brown and Morris, since the French observers did not determine what constituent of the wall is affected by it. Green appears, however, to have overlooked a later publication by Bourquelot (1899: 567) in which he states that when the solution of pectine was coagulated by pectase and this coagulum treated with the malt enzym solution it gradually disappeared and coincidently reducing sugar was found, showing that it was a process of hydrolysis. He considers the action of these two enzyms, pectase and pectinase, on the compounds of the pectic series analogous to that of rennet and trypsin, respectively, on casein, in that one causes coagulation of the soluble forms while the other liquefies the coagulum through hydrolysis. As confirmatory of his conclusions he cites experiments wherein he added the two enzyms simultaneously to the pectine solution. When the proportion of the pectase was larger as compared with the amount of pectinase there resulted first coagulation and then the gradual liquefaction of the coagulum. When the proportions were reversed no coagulation took place. These latter experiments would seem to disarm any suspicion that the solution of the clot as reported in the first experiment was due to bacterial development. It is, however, a matter of

regret that Bourquelot gives practically no details as to his methods in these experiments, since it is evident from his statements that the changes occupied considerable lengths of time; and one would wish full assurance of the absence of bacterial growth.

In some of his other work with enzym solutions he relied upon chloroform, in some on "thymol water," both of which, we have learned, must be used with painstaking, if bacterial growths are to be suppressed with certainty. In some cases he has depended upon frequently raising the temperature of the solutions to 50° C. to destroy bacteria.

In spite of these criticisms, however, it seems to us that the conclusions of Bourquelot and Herissey must be accepted, viz., that there is present in barley malt an enzym, their pectinase, which hydrolyzes pectine, and also an enzym, presumably the same, which hydrolyzes the pectic coagulum. Since this latter is regarded by most chemists, including Green, as calcium pectate and the same as the middle lamella in composition, the name pectinase becomes applicable to the middle lamella-dissolving enzym of barley malt.

The strongest objection to this dictum is that there may be insufficient ground for their conclusion that the action upon the pectine and the coagulum is due to one and the same enzym. These are closely related compounds and it seems to us their conclusion must be accepted until the contrary is proved. There is nothing in their publication to indicate whether or not they regarded their "pectinase" as capable of causing the solution of the hemicelluloses also. Since, however, they do not state to the contrary and later name only three enzyms as occurring in barley malt[18] (diastase, trehelase and pectinase), we are led to infer that they so regarded it, and therefore, as Green says, they did not clearly define their "pectinase" as different from Brown and Morris' cytolytic enzym, for which Grüss later proposed the name "cytase."

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[18] Bourquelot, Em. Sur l'hydrolyse des polysaccharides par les ferments soluble. *Jour. Pharm. et Chem.* 16: 581. 1902.

Newcombe (1899) made a comparative study of cytolytic enzyms in the course of which he repeated and verified the observations of Brown and Morris upon the barley enzym and secured similar soluble ferments from some other germinating seeds. He found the enzymic extract from the cotyledons of *Lupinus albus* to be strongly cytolytic and but feebly amylolytic. Extracts from both the cotyledons and the endosperm of *Phoenix dactylifera* showed cytolytic and amylolytic activity, and here again the cytolytic action was relatively greater. There was, however, a noteworthy difference between the two date-seed extracts in that the one from the cotyledons had much greater amylolytic strength and relatively weaker cytolytic activity. This showed that the action on starch and the action on cell wall were distinct and independent processes. This evidence was further strengthened by comparisons of these with barley malt extract and with taka-diastase, both of which were found relatively stronger in amylolytic action. This seems conclusive as against Reinitzer's contention that the cytolytic action was due to diastase.

Further comparisons showed also a lack of correlation between the rate of solution of the middle lamella and inner lamellae, respectively. Thus the five solutions were made to such a strength that all showed a like rate of action on starch. Sections of barley endosperm were then immersed in them and the periods necessary for complete solutions of inner and of middle lamellae, respectively, in each found to be as follows:

Source of extract.	Solution of inner lamella.	Solution of middle lamella.
Lupinus cotyledon	required 9 hours.	required 21 hours.
Date endosperm	" 9 "	" 118 "
Date cotyledon	" 21	" 118 "
Taka-diastase	" 94–116	" over 312 "
Barley malt	" 94–116 "	" " 312 "

These figures also serve to indicate the difference in the relative amylolytic and cytolytic activities discussed above.

Green in the second edition of his work on Fermentation (1901:105) cited these observations of Newcombe's as confirm-

ing his earlier idea that "there appear to be two varities of cytase, one attacking most readily the middle lamella, the other the layers deposited upon it."

It only remains to refer in this connection to the accounts of two other enzyms of the cytolytic class.

Effront (1897) obtained from the carob bean a ferment he calls caroubinase. This acts upon a peculiar carbohydrate caroubin, differing from both starch and cellulose, which he obtained not only from this bean but also from barley and rye. Caroubinase has been classed with the cytases, but differs from those previously discussed in that it withstands a temperature as high as 80° C. It is of interest in the present discussion only as suggesting that other classes of cytolytic enzym may be revéaled upon further investigation.

Wiesner (1885) states that there occurs in gum arabic an enzym capable of transforming cellulose into gum and mucilage. This apparently needs further study before acceptance, but it again suggests the same idea.

CLASSIFICATION AND NOMENCLATURE OF THE CYTOLYTIC ENZYMS.

In the first place we would again call attention to the fact that these studies have added strength to the argument that the cytolytic enzym or cytases stand in a class apart from the amyloiytic enzyms or disastases. This is evidenced by the uniformly lower point of thermal destruction of the cytases; by the fact that cytases occur which show no diastatic action whatever, e. g., that of *B. carotovorus;* by the further fact that diastases occur which show no cytolytic action whatever, e. g., that of saliva.[19] Where enzymic solutions show both cytolytic and amylolytic activity they have been found to exercise these in unlike ratios, sometimes one and sometimes the other predominating, as shown by Newcombe. The only conclusion permissible is that in such cases two enzyms occur in mixture in varying proportions.

[19] Cf. Brown, H. T., 1892:356.

As to the cytolytic enzyms, we are convinced that Green is right in his conclusion that these fall into two natural groups, the one active upon the pectic, and the other upon the cellulose elements of the cell membrane. Since both of these elements include a complex of chemical compounds we would naturally expect a corresponding variety to be shown in the enzyms which act upon them. There is, indeed, evidence that this does occur. The fuller understanding of the chemistry of the cell membranes must, however, precede such further subdivision of the enzyms acting upon each. For the present we can at least accept the following as representing well-defined groups of components in the simpler or less modified plant tissues: 1. True celluloses. 2. Hemicelluloses. 3. Pectic compounds. In the more modified tissues there are other compound celluloses, ligno-cellulose, etc., which do not here concern us.

Evidence is not lacking that there are enzyms capable of hydrolyzing the true celluloses, but further study is necessary before their relationships can be defined. The cytolytic enzyms, which have been studied in sufficient detail so that we can characterize them, act only upon the last two of these three classes. As already indicated, we consider these enzyms to be as clearly separable into two groups or kinds as are the wall elements upon which they act, and we believe it must conduce to clearness of understanding if a distinct name be accepted and defined for each of these kinds of enzym.

The enzym of *B. carotovorus* and the related soft-rot bacteria is a good example of one acting upon the pectic compounds, but not hydrolyzing the hemicelluloses. Such an enzym has heretofore been referred to usually as "cytase." If the cytolytic enzyms are to be differentiated some more specific name must be found. Following the custom of naming enzyms, pectase would be the right name had it not been applied to Fremy's clotting enzym. If one accepts the grouping of the celluloses outlined by Cross and Bevan and considers these pectic elements of the wall to occur in compound with cellulose or pecto-celluloses preference might be given to the name *pecto-*

cellulase. This is not free from objection, however, since their term pectocellulose was applied to a hypothetical compound made up of non-hydrolyzable cellulose elements and pectic elements which pass into solution under the influence of this enzym. This name if adopted would suggest an enzym capable of action on both these components alike.

All things considered, we favor the name *pectinase,* which was suggested by Bourquelot and Herissey, as already explained. An objection to this name is that it was originally applied to the enzym which hydrolyzes pectose. Later it was found that this same extract hydrolyzes the coagulum, or pectic clot. It was inferred that this latter action is due to the same enzym as the former. Although this was not demonstrated, it seems to us sufficiently probable to justify its acceptance as a satisfactory working hypothesis, and if so this name must be accepted for the enzym under discussion. As more broadly defined, then, *pectinase* is capable of hydrolyzing pectose when in solution so that it will no longer yield a clot under the influence of pectase, and also of hydrolyzing the pectic coagulum and the pectic elements in the cell wall, viz., the middle lamella and parts of the inner lamellae of certain tissues. As a further justification of the acceptance of the name pectinase in the broader sense we note a tendency in this direction in certain writings which have appeared since its promulgation.[20]

Bourquelot and Herissey did not so define their enzym as to exclude its action on hemicellulose; in fact, the barley malt solution with which their work was done does so act. As already explained, this hydrolytic action on hemicellulose predominates in the cytolytic action of taka-diastase, although action on the pectic compound occurs also. Since we have made some observations upon this taka preparation we will base our discussion on that. Two explanations are available for action such as occurs here, and in like cases where there is solution of both of these wall elements. The first is that only

[20] See use by Lepoutre (1902), also Oppenheimer (1901:193).

one kind of cytolytic enzym is present, which is allied to pectinase but differs from it in that it acts primarily on hemicellulose and to a less degree on the pectic elements. The second is that two distinct cytolytic enzyms are present in mixture, viz., a small amount of pectinase, which causes t e hydrolysis of the pectic elements, and a relatively larger amount of another enzym which acts on the hemicelluloses. Newcombe's results, referred to earlier in this paper, strongly favor the second of these two possible explanations and exclude the first.

Accepting the conclusion that there is an enzym other than pectinase in taka-diastase, barley, malt, etc., of which the hydrolytic action is chiefly or wholly on the hemicellulose elements of the cell membrane, we need a distinctive name for that also. The one introduced by Oppenheimer (1901 : 187), cellulase, seems fit except that it is too general. It implies an activity on the celluloses generally, and especially on the celluloses proper. This enzym, which acts only on the hemicellulose, may better be termed *hemicellulase.* This is a self-explanatory name and leaves the name cellulase to be applied either in a more general sense to all cellulose enzyms, including this hemicellulase, or, as would be preferable in our opinion, reserving it for application to the enzyms which hydrolyze the celluloses proper, as recently studied by Omelianski (1902). These terms, pectinase and cellulase, have heretofore been used rather vaguely as synonyms of Grüss' term cytase, i. e., as applicable to cytohydrolysts generally. If they be restricted to the more exact usage defined above, it leaves the words cytohydrolyst, or better cytolyst, and cytase as convenient and satisfactory terms for use in the broader sense to include in a general or indefinite way both of the above, and indeed any other related enzyms capable of hydrolyzing the cell membranes.

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REPORT

OF THE

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TABLE OF CONTENTS.

REPORT OF THE BOTANICAL DEPARTMENT.

POTATO SPRAYING EXPERIMENTS IN 1908.*

F. C. STEWART, G. T. FRENCH AND F. A. SIRRINE.

SUMMARY.

This bulletin gives the results of the seventh year's work in the ten-year series of potato spraying experiments begun in 1902. During 1908 the experiments were conducted along the same lines as in previous years. Twenty-seven separate experiments are reported.

TEN-YEAR EXPERIMENTS.

At Geneva, six sprayings increased the yield 39 bu. per acre and three sprayings increased it 29½ bu. although both early and late blight were wholly absent and there were but few flea beetles. The chief trouble was tip burn. There was no rot. At Riverhead the gain due to five sprayings was 15.3 bu. per acre and to three sprayings 10.75 bu. Here, the chief enemies were the flea beetle and early blight. There was no late blight and no rot.

FARMERS' BUSINESS EXPERIMENTS.

In fourteen farmers' business experiments, including 200 acres, the average gain due to spraying was 18.5 bu. per acre; the average total expense of spraying, $4.30 per acre; and the average net profit, $8.53 per acre. In five of the experiments spraying was unprofitable.

VOLUNTEER EXPERIMENTS.

Eleven volunteer experimenters reported gains averaging 66.3 bu. per acre. These experiments do not fairly represent the results obtained from spraying in 1908.

The chief trouble with potatoes in New York in 1908 was tip burn, caused primarily by dry weather, but aggravated by flea beetles, leaf hoppers and other insects. Early blight was rare and late blight and rot almost wholly absent. The experiences of 1908 indicate that it is unwise to neglect spraying in dry seasons.

* A reprint of Bulletin No. 311.

INTRODUCTION.

Does it pay to spray potatoes in New York? Potato growers have been asking this question for fifteen years or more. It is well known that in seasons when blight is destructive spraying will check the blight and considerably increase the yield; but the majority of potato growers have doubted that spraying is profitable on the average. They argue that blight does not appear every year. In some seasons it causes but little if any damage, yet the spraying must be done regularly because it is impossible to foretell the appearance of blight. The result is that in some seasons spraying is profitable while in others it is unprofitable and they doubt that the aggregate gain will pay the expense of spraying for a series of years.

This Station has set out to find an answer to the above question. The investigation was begun in 1902 and is to be continued until 1912. During ten consecutive years numerous potato spraying experiments will be made each year and at the end of the period the results will be averaged. The experiments are of three kinds: (1) Station ten-year experiments; (2) farmers' business experiments; (3) farmers' volunteer experiments. The ten-year experiments (two each year) are carried out entirely by the Station. The business experiments (13 to 15 each year) are conducted by farmers in coöperation with the Station. The volunteer experiments are carried out entirely by farmers.

Bulletins previously published are:

No. 221. Potato Spraying Experiments in 1902;
No. 241. Potato Spraying Experiments in 1903;
No. 264. Potato Spraying Experiments in 1904;
No. 279. Potato Spraying Experiments in 1905;
No. 290. Potato Spraying Experiments in 1906;
No. 307. Potato Spraying Experiments in 1907.

SUMMARY OF RESULTS OBTAINED IN TEN-YEAR EXPERIMENTS PRIOR TO 1908.

RESULTS IN 1902.

TABLE I.—YIELD BY SERIES AT GENEVA IN 1902.

Series.	Rows.[1]	Dates of spraying.	Yield per acre.[2] Bu.	lbs.
I	1, 4, 7 and 13	July 10, 23 and Aug. 12	317	41
II	2, 5, 8 and 14	June 25, July 10, 23, 30, Aug. 12, 26 and Sept. 10	342	36
III	3, 6, 9 and 15	Not sprayed	219	4

[1] Rows 10, 11 and 12 omitted because of probable error.
[2] The yields given in Tables I to XII relate to marketable tubers only.

Increase in yield due to spraying three times, 98½ *bu. per acre.*

Increase in yield due to spraying seven times, 123½ *bu. per acre.*

The unsprayed rows died two weeks earlier than the sprayed rows, owing chiefly to a severe attack of late blight. They were also somewhat injured by flea beetles, but there was no early blight. On unsprayed rows the loss from rot was 7½ per ct.; on sprayed rows only an occasional tuber.

TABLE II.—YIELD BY SERIES AT RIVERHEAD IN 1902.

Series.	Rows.	Dates of spraying.	Yield per acre. Bu.	lbs.
I	2, 5, 8 and 11	May 26, June 20 and July 12	295	20
II	1, 4, 7 and 10	May 26, June 3, 20, 30, July 11, 23 and Aug. 5	312	35
III	3, 6, 9 and 12	Not sprayed	267	40

Increase in yield due to spraying three times, 27¾ *bu. per acre.*

Increase in yield due to spraying seven times, 45 *bu. per acre.*

In this experiment there were only traces of early blight and no late blight. The larger yield on sprayed rows was due to partial protection against flea beetles which were rather plentiful at times. There was no rot.

RESULTS IN 1903.

TABLE III.—YIELD BY SERIES AT GENEVA IN 1903.

Series.	Rows.	Dates of spraying.	Yield per acre. Bu.	lbs.
I.	1, 4, 7, 10 and 13.	July 14, 28 and Aug. 26....	262	—
II..........	2, 5, 8, 11 and 14.	July 7, 21, Aug. 7, 21 and Sept. 3..................	292	10
III..........	3, 6, 9, 12 and 15.	Not sprayed..............	174	20

Increase in yield due to spraying three times, 88 *bu. per acre.*
Increase in yield due to spraying five times, 118 *bu. per acre.*

Three sprayings prolonged the life of the plants 11 days; five sprayings, 18 days. There was no early blight and the injury from flea beetles was only slight. Late blight was again the chief enemy. The loss from rot was even less than in 1902.

TABLE IV.—YIELD BY SERIES AT RIVERHEAD IN 1903.

Series.	Rows.	Dates of spraying.	Yield per acre. Bu.	lbs.
I...........	1, 4, 7 and 10....	June 5, July 22 and Aug. 7..	246	45
II..........	2, 5, 8 and 11....	June 5, 24, July 7, 22 and Aug. 7.................	263	10
III..........	3, 6, 9 and 12....	Not sprayed..............	207	10

Increase in yield due to spraying three times, 39½ *bu. per acre.*
Increase in yield due to spraying five times, 56 *bu. per acre.*

The sprayed rows outlived those unsprayed by several days. Late blight and flea beetles were the chief enemies. Early blight, also, caused slight damage. On the unsprayed rows the loss from rot was two per ct.; on those sprayed, practically nothing.

RESULTS IN 1904.

TABLE V.—YIELD BY SERIES AT GENEVA IN 1904.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I.	1, 4, 7, 10 and 13.	July 13, 27 and Aug. 15.	344	30
II.	2, 5, 8, 11 and 14.	July 8, 22, Aug. 1, 15 and 29.	386	40
III.	3, 6, 9, 12 and 15.	Not sprayed.	153	25

Increase in yield due to spraying three times, 191 *bu. per acre.*
Increase in yield due to spraying five times, 233 *bu. per acre.*

Spraying prolonged the life of the plants 25 days. Late blight was the only trouble. Both on sprayed and unsprayed rows there was a little rot at digging time. In storage, the sprayed potatoes rotted most. Spraying materially improved the cooking qualities.

TABLE VI.—YIELD BY SERIES AT RIVERHEAD IN 1904.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I.	1, 4, 7 and 10.	June 14, July 21, and Aug. 9.	257	58
II.	2, 5, 8 and 11.	June 14, 27, July 11, 26, Aug. 9 and 22.	297	45
III.	3, 6, 9 and 12.	Not sprayed.	201	25

Increase in yield due to spraying three times, 56½ *bu. per acre.*
Increase in yield due to spraying six times, 96⅓ *bu. per acre.*

The larger yield on sprayed rows was due chiefly to partial protection against flea beetles which were unusually abundant. Both early and late blight also present. The loss from rot was three per ct. on Series I., one per ct. on Series II., and six per ct. on Series III.

RESULTS IN 1905.

TABLE VII.—YIELD BY SERIES AT GENEVA IN 1905.

Series.	Rows.[1]	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	4, 7, 10 and 13	July 3, August 7 and 25	228	45
II	5, 8, 11 and 14	June 29, July 13, 27, Aug. 12 and 24	241	15
III	6, 9, 12 and 15	Not sprayed	121	52

[1] Rows 1, 2 and 3 omitted because of error.

Increase in yield due to spraying three times, 107 *bu. per acre.*
Increase in yield due to spraying five times, 119½ *bu. per acre.*

From the combined attack of flea beetles, tip-burn and late blight the unsprayed rows died fully two weeks earlier than the sprayed ones. Spraying reduced the loss from rot at the rate of 41 bushels per acre. There was no subsequent rot in storage.

TABLE VIII.—YIELD BY SERIES AT RIVERHEAD IN 1905.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13	June 14, July 18 and Aug. 11	253	—
II	2, 5, 8, 11 and 14	June 14, 30, July 14, 28 and Aug. 11	303	41
III	3, 6, 9, 12 and 15	Not sprayed	221	38

Increase in yield due to spraying three times, 31½ *bu. per acre.*
Increase in yield due to spraying five times, 82 *bu. per acre.*

Late blight caused no injury in this experiment and there was not even a trace of rot. Flea beetles and early blight were the enemies fought.

RESULTS IN 1906.

TABLE IX.—YIELD BY SERIES AT GENEVA IN 1906.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13.	July 9, August 10 and 30	227	25
II	2, 5, 8, 11 and 14.	July 6, 20, Aug. 6, 20 and 21.	258	40
III	3, 6, 9, 12 and 15.	Not sprayed	195	40

Increase in yield due to spraying three times, 31¾ bu. per acre.
Increase in yield due to spraying five times, 63 bu. per acre.

Late blight, early blight, flea beetles and tip burn were all factors in this experiment, but none of them caused much damage. Spraying controlled blight and flea beetles completely and tip burn partially. The loss from rot was negligible, only four rotten tubers being found in the entire experiment.

TABLE X.—YIELD BY SERIES AT RIVERHEAD IN 1906.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I	1, 4, 7, 10 and 13.	June 12, July 18 and Aug. 6.	172	—
II	2, 5, 8, 11 and 14.	June 12, 25, July 10, 25 and Aug. 6	203	45
III	3, 6, 9, 12 and 15.	Not sprayed	150	30

Increase in yield due to spraying three times, 21½ bu. per acre.
Increase in yield due to spraying five times, 53¼ bu. per acre.

In the experiment at Riverhead the principal enemies were late blight and flea beetles, there being a moderate attack of both. Early blight was not sufficiently abundant to cause material injury. There was no loss from rot.

RESULTS IN 1907.

TABLE XI.—YIELD BY SERIES AT GENEVA IN 1907.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I.	1, 4, 7, 10 and 13.	July 15, Aug. 9 and 24.	220	15
II.	2, 5, 8, 11 and 14.	July 15, 24, Aug. 9, 24 and Sept. 17.	249	50
III.	3, 6, 9, 12 and 15.	Not sprayed.	176	10

Increase in yield due to spraying three times, 44 *bu. per acre.*
Increase in yield due to spraying five times, 73⅗ *bu. per acre.*

Late blight and rot were wholly absent and early blight appeared only in traces. There was some tip burn and a light attack of flea beetles. Considering the seemingly small amount of damage done by blight and insects it is remarkable that spraying should have increased the yield so much.

TABLE XII.—YIELD BY SERIES AT RIVERHEAD IN 1907.

Series.	Rows.	Dates of spraying.	Yield per acre.	
			Bu.	*lbs.*
I.	1, 4, 7, 10 and 13.	June 19, July 25 and Aug. 15	186	45
II.	2, 5, 8, 11 and 14.	June 19, July 2, 17, 31, Aug. 15 and 29.	200	5
III.	3, 6, 9, 12 and 15.	Not sprayed.	168	50

Increase in yield due to spraying three times, 18 *bu. per acre.*
Increase in yield due to spraying six times, 31¼ *bu per acre.*

There was some early blight, but no late blight. Flea beetles were plentiful and caused much damage. The large yield of the sprayed rows is to be attributed to their partial protection against flea beetles and early blight.

DETAILS OF THE TEN-YEAR EXPERIMENTS IN 1908.

AT GENEVA.

In 1908, the experiment was carried out in very nearly the same manner as in previous years. As usual, there were 15 rows 290.4 feet long by three feet wide. Planting was done by hand May 25. The variety was Rural New Yorker No. 2. The plat of land used was the same as that used for the experiment in 1903 and 1905. The soil was heavy clay loam and the previous crop alfalfa.

The five rows constituting Series I were sprayed three times —twice with bordeaux mixture and paris green and once with bordeaux alone—the dates being July 3, 17 and Aug. 3.

The five rows constituting Series II were sprayed six times —twice with bordeaux mixture and paris green and four times with bordeaux alone—the dates being July 3, 17, Aug. 3, 18, Sept. 1 and 16.

The five rows constituting Series III (Check) were not sprayed at all with bordeaux, but were treated twice (July 3 and 20) with paris green in lime water to control bugs.

The spraying was done very thoroughly with a knapsack sprayer. The bordeaux mixture used contained six pounds of copper sulphate to each 50 gallons and lime considerably in excess of the amount required to satisfy the potassium ferrocyanide test. Whenever paris green was used it was applied at the rate of one pound to 50 gallons.

It was the intention to apply poison to the unsprayed rows on the same date that Series I and II were sprayed the second time (July 17); but rain interfered, making it impossible to treat the unsprayed rows until July 20. During this period bugs were active and the unsprayed rows were slightly injured by them. After July 20 there was no further trouble with bugs. There was no early blight and no late blight. Flea beetles caused a little damage to the unsprayed rows, most of which occurred after September 1. The chief trouble was tip burn, which was quite severe. As late as September 1 the

difference between sprayed and unsprayed rows was slight. However, the sprayed rows of Series II outlived the unsprayed rows of Series III by about five days, owing, apparently, to the smaller amount of tip burn and flea beetle injury on the sprayed rows.

The potatoes were dug by hand and sorted and weighed in the usual manner. The yields are shown in the following table:

TABLE XIII.—YIELDS IN THE EXPERIMENT AT GENEVA IN 1908.

Rows.	Treatment.	Yield per row.[4]		Yield per acre.			
		Marketable.	Culls.	Marketable.		Culls.	
		Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
1	Sprayed 3 times	202	6	168	20	5	—
2	Sprayed 6 times	189½	2	157	55	1	40
3	Unsprayed	143	6	119	10	5	—
4	Sprayed 3 times	197	6	164	10	5	—
5	Sprayed 6 times	203½	7	169	35	5	50
6	Unsprayed	148	8	123	20	6	40
7	Sprayed 3 times	196	5	163	20	4	10
8	Sprayed 6 times	187	7	155	50	5	50
9	Unsprayed	167	5	139	10	4	10
10	Sprayed 3 times	173	7	144	10	5	50
11	Sprayed 6 times	199	6	165	50	5	—
12	Unsprayed	143	6	119	10	5	—
13	Sprayed 3 times	166	4	138	20	3	20
14	Sprayed 6 times	212	5	176	40	4	10
15	Unsprayed	156	8	130	—	6	40

[4] Rows 290.4 feet long by three feet wide making the area of each row exactly one-fiftieth acre.

Yield by series.—The five rows sprayed three times constitute Series I and the average yield of these rows makes the yield for Series I. The yields given for Series II and III have been computed in the same way. The yield by series is shown in the following table:

Table XIV.—Yield by Series at Geneva in 1908.

Series.	Rows.	Dates of spraying.	Yield per acre.[5]	
			Bu.	*lbs.*
I..........	1, 4, 7, 10 and 13.	July 3, 17 and Aug. 3......	155	40
II..........	2, 5, 8, 11 and 14.	July 3, 17, Aug. 3, 18, Sept. 1 and 16..............	165	10
III.........	3, 6 ,9, 12 and 15.	Not sprayed..............	126	10

[5] Marketable tubers only.

Increase in yield due to spraying three times, 29½ bu. per acre.
Increase in yield due to spraying six times, 39 bu. per acre.

AT RIVERHEAD.

The experiment at Riverhead was carried out in practically the same manner as the one at Geneva. There were fifteen rows 290.4 feet long by three feet wide. The seed tubers, which were of the variety Carman No. 1, were planted April 20 with a Robbins potato planter. The previous crop had been potatoes. The soil was sandy loam and well drained.

The five rows of Series I were sprayed three times—twice (June 11 and July 9) with bordeaux and paris green and once (Aug. 4) with bordeaux alone. They were also treated once (June 25) with paris green in lime water.

The five rows of Series II were sprayed five times—three times (June 11, 25 and July 9) with bordeaux and paris green and twice (July 24 and Aug. 4) with bordeaux alone.

The five rows of Series III (Check) were not sprayed at all with bordeaux, but were treated three times (June 11, 25 and July 9) with paris green in lime water to control bugs.

The bordeaux mixture used was prepared in the same manner as in the Geneva experiment (see page 223). Whenever paris green was used it was applied at the rate of one pound to 50 gallons. All of the applications were made with a knapsack sprayer and the work done very thoroughly.

In this experiment there was some early blight and a moderate attack of flea beetles, but no late blight. The season

was too dry for late blight. During July the plants were considerably injured by plant lice.

At digging time the potatoes were sorted and weighed in the usual manner. The yields were as follows:

TABLE XV.—YIELDS IN THE EXPERIMENT AT RIVERHEAD IN 1908.

Rows.	Treatment.	Yield per row.[6]		Yield per acre.			
		Marketable.	Culls.	Marketable.		Culls.	
		Lbs.	*Lbs.*	*Bu.*	*lbs.*	*Bu.*	*lbs.*
1	Sprayed 3 times.......	189½	4	157	55	3	20
2	Sprayed 5 times.......	202	3½	168	20	2	55
3	Unsprayed............	163½	3½	136	15	2	55
4	Sprayed 3 times.......	159½	2	132	55	1	40
5	Sprayed 5 times.......	173	3½	144	10	2	55
6	Unsprayed............	172	3	143	20	2	30
7	Sprayed 3 times.......	177	4	147	30	3	20
8	Sprayed 5 times.......	178	5	148	20	4	10
9	Unsprayed............	147½	4½	122	55	3	45
10	Sprayed 3 times.......	179	3	149	10	2	30
11	Sprayed 5 times.......	179½	4	149	35	3	20
12	Unsprayed............	184	4	153	20	3	20
13	Sprayed 3 times.......	180½	4	150	25	3	20
14	Sprayed 5 times.......	180½	5	150	25	4	10
15	Unsprayed............	154	3	128	20	2	30

[6] Rows 290.4 feet long by three feet wide making the area of each row exactly one-fiftieth acre.

TABLE XVI.—YIELD BY SERIES AT RIVERHEAD IN 1908.

Series.	Rows.	Dates of spraying.	Yield per acre.[7]	
			Bu.	*lbs.*
I...........	1, 4, 7, 10 and 13.	June 11, July 9 and Aug. 4..	147	35
II..........	2, 5, 8, 11 and 14.	June 11, 25, July 9, 24 and Aug. 4..................	152	10
III.........	3, 6, 9, 12 and 15.	Not sprayed..............	136	50

[7] Marketable tubers only.

Increase in yield due to spraying three times, 10¾ bu. per acre.
Increase in yield due to spraying five times, 15⅓ bu. per acre.

In 1908, as in each of the other years during which these experiments have been running, the gain from spraying has been considerably less at Riverhead than at Geneva. The amount of this difference is shown in the following table:

SUMMARY OF RESULTS OBTAINED IN THE TEN-YEAR EXPERIMENTS, 1902-1908.

The following table shows the results obtained in the ten-year experiments during the first seven years:

TABLE XVII.—SUMMARY OF THE TEN-YEAR EXPERIMENTS FOR SEVEN YEARS

Year.	AT GENEVA.		AT RIVERHEAD.	
	Gain per A. due to spraying every two weeks	Gain per A. due to spraying three times.	Gain per A. due to spraying every two weeks	Gain per A. due to spraying three times.
	Bu.	*Bu.*	*Bu.*	*Bu.*
1902	123½	98½	45	27⅔
1903	118	88	56	39½
1904	233	191	96	56½
1905	119	107	82	31½
1906	63	32	53	21½
1907	73⅔	44	31	18
1908	39	29½	15⅓	10¾
Average	110	84	54	29⅓

FARMERS' BUSINESS EXPERIMENTS.

During the season of 1908 fourteen farmers in different parts of the State conducted business experiments for the Station. The object of these experiments is to determine the actual profit in spraying potatoes under farm conditions. The methods employed were essentially the same as in previous years. An accurate record was kept of all of the expense of spraying, including labor, chemicals and wear of machinery. In each experiment a strip of three to six rows was left unsprayed for comparison.

In order to bring the account of the experiments within the required space limit it has been necessary to omit many interesting details.

"Spraying," as used in this bulletin, means the application of bordeaux mixture exclusively. The application of paris green or arsenite of soda in lime water is not called spraying.

Whenever "arsenite of soda" is mentioned it should be understood to mean the stock solution prepared by the Kedzie formula—one pound white arsenic, four pounds sal soda and one gallon of water boiled together twenty minutes.

By "test rows" is meant the rows used in determining the amount of the increase in yield due to spraying. These are, usually, the middle unsprayed row and the second sprayed row on either side.

The yields given are for marketable tubers only.

The price used in computing the value of the increased yield is, in every case, the market price for potatoes in the locality where the experiment was made on the date on which the test rows were dug.

THE WILLINK EXPERIMENT.

Conducted by M. J. Buntin, Willink, N. Y. Twenty acres of potatoes, variety Snowflake Jr., were sprayed three times with a two-horse E. C. Brown Co. "Auto" sprayer carrying one nozzle per row and covering four rows at each passage. The water used in the preparation of the bordeaux was pumped by hand from a stream about 80 rods distant from the potato field. Three rows 80 rods long were left unsprayed for a check. So few bugs appeared that poisoning of the check rows was not required. As a precautionary measure arsenite of soda was used with the bordeaux in the first spraying, but this seems to have been quite unnecessary.

The expense account contained the following items:

360 lbs. copper sulphate @ 6c	$21.60
300 lbs. lime @ 62½c. per 100	1.88
40 lbs. sal soda @ 1c	.40
10 lbs. white arsenic @ 4½c	.45
7½ days labor for man @ $1.50	11.25
7½ days labor for team @ $2.00	15.00
Wear of sprayer	5.00
Total	$55.58

The check rows were 80 rods long by 32 in. wide. Owing to the weather being disagreeable at digging time the test was confined to a representative section 300 feet long. The yields were as follows:

Average of two sprayed rows, 121 lbs.=109.8 bu. per acre.
Middle unsprayed row, 113 lbs.=102.6 bu. per acre.
Gain, 7.2 bu. per acre.

What caused the greater yield on the sprayed rows is not clear. There was no blight of any kind and only a few flea beetles.

The market price of potatoes being 70 cents per bushel 7.2 bu. have a value of $5.04. After deducting the expense of spraying there remains *a net profit of $2.26 per acre.*

THE BATAVIA EXPERIMENT.

Conducted by G. A. Prole, Batavia, N. Y. Thirteen acres of potatoes were sprayed five times with a two-horse, four-row "Iron Age" sprayer carrying one nozzle per row. Water was obtained from a well about eight rods from the field. The pumping was done by a windmill. Poison (arsenite of soda) was used with the bordeaux in the first spraying at the rate of 3 qts. of the stock solution to 50 gallons. The check consisted of a strip of three rows 1,424 ft. long by 34 in. apart. These were treated with paris green twice—July 11 and Aug. 18. During the last three weeks of growth the check rows were plainly somewhat inferior to the adjacent sprayed rows. There was no blight, but the check rows had suffered more from the attack of flea beetles and bugs. Inasmuch as the check rows received two applications of poison while the sprayed rows received but one Mr. Prole considers that the sprayed rows did not have an unfair advantage.

The expense account contained the following items:

392 lbs. copper sulphate @ 6¼c	$24.50
4 bu. lime @ 25c	1.00
32 lbs. sal soda @ 2c	.64
8 lbs. white arsenic @ 12c	.96
67½ hrs. labor for man @ 20c	13.50
135 hrs. labor for horse @ 5c	6.75
Wear on sprayer	5.00
Total	$52.35

The test rows (Sir Walter Raleigh) yielded as follows:

Two sprayed rows, 1,818 lbs.=163.6 bu. per acre.
Middle unsprayed row, 752 lbs.=135.3 bu. per acre.
Gain, 28.3 bu. per acre.

At 55 cents per bushel 28.3 bu. have a market value of $15.56. Subtracting the expense of spraying, $4.03 per acre, we have left *a net profit of $11.53 per acre.*

THE ELMIRA EXPERIMENT.

Conducted by John Strouse, Elmira, N. Y. Nineteen acres of potatoes (in three lots) were sprayed all over four times and 13 acres a fifth time. The sprayer was a two-horse, 6-row "Perfection" sprayer carrying one nozzle per row. Part of the water for the bordeaux came from a creek near the field and the remainder from a well about 80 rods distant. In two of the lots 3-row checks were left. Both checks were treated with paris green once—about July 12. In the first spraying paris green was used with the bordeaux at the rate of two pounds to 50 gallons. In one of the later sprayings arsenite of soda was used with the bordeaux at the rate of 4 qts. of the stock solution to 50 gals. The checks were not injured by bugs. There was no blight and very few flea beetles. Lot No. 1 suffered severely from tip burn, but Lots II and III were very little injured by anything.

The expense account contained the following items:

380 lbs. copper sulphate @ 6c	$22.80
9 sacks lime @ 30c	2.70
Sal soda and white arsenic	3.67
52 hrs. labor for man @ 15c	7.80
26 hrs. labor for team @ 25c	6.50
Wear of sprayer	5.00
Total	$48.47

The test rows yielded as follows:

Lot No. 1. Sprayed five times; rows 485 ft. by 3 ft.
Two sprayed rows, 230 lbs.=57.4 bu. per acre.
Middle unsprayed row, 113 lbs.=55.9 bu. per acre.
Gain, 1.5 bu. per acre.

Lot No. III. Sprayed 4 times; rows 517 ft. by 39 in.
Two sprayed rows, 424 lbs.=91.6 bu per acre.
Middle unsprayed row, 204 lbs.=88.1 bu per acre.
Gain, 3.5 bu. per acre.

The average gain in the two tests being 2.5 bu. per acre, worth (at 65 cts. per bu.) $1.62, and the average expense of spraying being $2.45 per acre, there was *a loss of* 83 *cents per acre.*

THE VICTOR EXPERIMENT.

Conducted by C. E. Green, Victor, N. Y. Ten acres of potatoes were sprayed twice with a one-horse, home-made, four-row sprayer carrying one nozzle per row. The dates of spraying were July 10 and 27. The bordeaux used was of the 4-5-50 formula and the water used in its preparation had to be hauled about 150 rods. In the second spraying arsenite of soda was used with the bordeaux. On the same date the four check rows were treated with arsenite of soda in lime water. During the whole season there was no marked difference between the sprayed and unsprayed rows. Some damage was done by flea beetles, but none whatever by blight. No rot was found at digging time.

The expense account contained the following items:

80 lbs. copper sulphate @ 6½c	$5.20
100 lbs. lime @ ½c	.50
100 lbs. sal soda @ 3c	3.00
25 lbs. white arsenic @ 12½c	3.13
16 hrs. man labor	3.00
16 hrs. horse labor	1.50
Extra man to prepare bordeaux	2.00
Wear of sprayer	1.00
Total	$19.33

The test rows were of the variety Sir Walter Raleigh. No representative of the Station was present at the digging. The rows were measured and the potatoes weighed by Mr. Green. The rows were 618 ft. long by 34 in. wide.

The yields were as follows:

One sprayed row, 234 lbs.=97 bu. per acre.
One check row, 189 lbs.=78.3 bu. per acre.
Gain, 18.7 bu. per acre.

The market price of potatoes at digging time being 60 cents per bushel the gain of 18.7 bu. had a value of $11.22. After deducting the expense of spraying, which is $1.93 per acre, there remains *a net profit of $9.29 per acre.*

THE INTERLAKEN EXPERIMENT.

Conducted by F. C. and L. B. Bradley, Interlaken, N. Y. Ten acres of potatoes, variety Carman No. 3, were sprayed four times—June 27, July 10, 28, and Aug. 10. The sprayer used was a two-horse, four-row "Watson" sprayer carrying one nozzle per row in the first two sprayings and two nozzles per row in the last two. Part of the bordeaux used was of the regular 4-4-50 formula and the remainder soda bordeaux. Water was obtained from a stream about 30 rods from the potato field. Paris green, at the rate of one-half pound to fifty gallons, was applied with the bordeaux in two sprayings, but it appears that the second application was unnecessary. Three rows were left unsprayed for a check. These were treated with paris green once. There was no blight whatever and only a moderate amount of damage done by flea beetles. Tip burn was severe; also, many plants died prematurely from an unknown cause, although the crop was given excellent care and cultivation. There was no appreciable difference between sprayed and unsprayed rows:

The expense account contained the following items:

230 lbs. copper sulphate @ 6½c	$14.95
170 lbs. lime @ 1½c	2.55
50 lbs. sal soda @ 1¼c	.63
10 lbs. paris green @ 34½c	3.45
53 hrs. man labor @ 20c	10.60
37 hrs. team labor @ 10c	3.70
Wear of sprayer	2.00
Total	$37.88

The test rows were 893 x 3 ft. They yielded as follows:

Two sprayed rows, 603 lbs.=81.7 bu. per acre.
Middle check row, 312.5 lbs.=84.7 bu. per acre.
Loss, 3 bushels per acre.

A carload of the potatoes was sold directly from the field at 57 cents per bushel. At this price, 3 bu. have a value of $1.71. Adding to this the expense of spraying, $3.79 per acre, the total LOSS *is shown to be $5.50 per acre.*

THE GROTON EXPERIMENT.

Conducted by E. A. Landon, Groton, N. Y., who sprayed 8¾ acres of potatoes five times on the following dates: July 7, 16, 27, Aug. 18 and 25. The sprayer was a two-horse, six-row "Aroostook" sprayer carrying two nozzles per row. The bordeaux used was of the 4-4-50 formula. The water required for its preparation was pumped by hand from a stream at one side of the field. Bugs were kept under control by using paris green with the bordeaux in three sprayings at the rate of one-half pound to 50 gallons. The check rows, of which there were four, were also treated three times with paris green. Early and late blight were both absent, but flea beetles and tip burn caused much damage. The spraying checked the flea beetles somewhat, but the difference between sprayed and unsprayed rows was not marked at any time.

The items of expense were as follows:

300 lbs. copper sulphate @ 8c	$24.00
300 lbs. lime @ 1c	3.00
25 lbs. paris green @ 28c	7.00
Sprayer, man and team, hired for 5 days @ $5 per day	25.00
2½ days labor for extra man @ $2	5.00
Total	$64.00

The test rows, which were of the variety State of Maine, were 650 ft. long by three feet wide. They yielded as follows:

Two sprayed rows, 715 lbs.=133.1 bu per acre.
Two unsprayed rows, 607 lbs.=113 bu. per acre.
Increase in yield due to spraying, 20.1 bu per acre.

The market price of potatoes being 65 cents per bushel the value of the increase is $13.06. If we subtract the expense of spraying, $7.31 per acre, there remains *a net profit of $5.65 per acre.*

THE STERLING STATION EXPERIMENT.

Conducted by A. E. Curtis, Sterling Station, N. Y. One field of 5 acres was sprayed 6 times; another of 4 acres, 5 times; and a portion of a third field containing 15 acres, 5 times. The sprayer was a 1-horse, 4-row, home-made affair. A four-row check was left in each field. There were so few bugs that it was unnecessary to use any poison for them. No late blight appeared. In all three fields there were a few flea beetles. Field No. 3 suffered severely from tip burn, but in the other fields it was not serious. In Field No. 1 the unsprayed rows were slightly injured by early blight. Here, there was some contrast between sprayed and unsprayed rows. In the other two fields there was little or no contrast. The following expense account covers only Fields 1 and 2 (9 acres):

269 lbs. copper sulphate @ 6c	$16.14
433 lbs. lime @ ¾c	3.25
75 hrs. labor for man @ 15c	11.25
75 hrs. labor for horse @ 10c	7.50
Wear of sprayer	10.00
Total	$48.14

The test rows showed the following yields:

Field No. 1. Sprayed six times. Rows 957 x 3 ft.
Two sprayed rows, 784 lbs.=99.1 bu. per acre.
Two unsprayed rows, 640 lbs.=80.9 bu. per acre.
Gain, 18.2 bu. per acre.

Field No. 2. Sprayed five times. Rows 818 x 3 ft.
Two sprayed rows, 754 lbs.=111.5 bu. per acre.
Two unsprayed rows, 600 lbs.=88.7 bu. per acre.
Gain, 22.8 bu. per acre.

Field No. 3. Sprayed five times. Rows 1,243 x 3 ft.
Two sprayed rows, 726 lbs.=70.7 bu. per acre.
Two unsprayed rows, 518 lbs.=50.4 bu. per acre.
Gain, 20.3 bu. per acre.

In the three tests the average gain was 20.4 bu. per acre, worth, at 60c. per bu., $12.24. Assuming that the expense of 5 sprayings in Field No. 3 was the same as for 5 sprayings in Field No. 2, the average expense of spraying was $5.18 per acre. Hence there was *a net profit of $7.06 per acre.*

THE EAST SYRACUSE EXPERIMENT.

Conducted by M. W. Garrett, East Syracuse, N. Y. Four acres of potatoes, variety Norcross, were sprayed five times. The dates of spraying were July 4, 11, 24 and 29 and Aug. 8. The sprayer was a one-horse, four-row "Iron Age" sprayer which carried one nozzle per row in the first two sprayings and two nozzles per row in the last three sprayings. The bordeaux used was of the 6-6-50 formula. Water had to be pumped by hand and hauled about 50 rods. In all five sprayings arsenite of soda was used with the bordeaux at the rate of two quarts of the stock solution to 50 gallons. The check consisted of four rows. These were treated three times with paris green. Both kinds of blight and flea beetles were absent. The only trouble was a very severe attack of tip burn. For some unknown reason the unsprayed rows made a slightly larger growth and remained green a little longer than the sprayed rows. Such a condition of affairs has not been observed in any of our previous experiments.

The expense account contained the following items:

125 lbs. copper sulphate @ 5½c.	$6.88
100 lbs. lime @ ½c.	.50
32 lbs. sal soda @ 1½c.	.48
8 lbs. white arsenic @ 20c.	1.60
30 hrs. man labor @ 15c.	4.50
15 hrs. horse labor @ 10c.	1.50
Wear of sprayer	5.00
Total	$20.46

The test rows (524.5 x 3 ft.) yielded as follows:

Two sprayed rows, 488 lbs.=133.4 bu. per acre.
Two unsprayed rows, 578.5 lbs.=112.6 bu. per acre.
Loss, 20.8 bu. per acre.

At 90 cents per bushel 20.8 bushels of potatoes have a market value of $18.72. To this must be added the expense of spraying, $5.12 per acre, which makes *the total loss $23.84 per acre.*

THE OGDENSBURG EXPERIMENT.

Conducted at Ogdensburg, N. Y., by Andrew Tuck, who sprayed five and one-half acres of potatoes seven times on the following dates: July 17, 24, 31, Aug. 10, 19, 29 and Sept. 7. The sprayer used was a one-horse, four-row "Aspinwall" sprayer carrying one nozzle per row. The bordeaux was of the 5-5-50 formula made with water pumped by hand from a well within a few rods of the field. Paris green (two pounds to 50 gallons) was used with the bordeaux in the first four sprayings. The three check rows also were treated with paris green four times on the same dates. The writers did not see this experiment until digging time. Mr. Tuck reports that by Aug. 10 the unsprayed rows were markedly inferior to the sprayed ones owing to the ravages of some kind of blight. He thinks it was not due to dry weather. The unsprayed rows were not injured by bugs or flea beetles. No rotten tubers were found at digging time.

The expense account contained the following items:

120 lbs. copper sulphate @ 7½c	$9.00
120 lbs. lime	1.00
30 lbs. paris green @ 31c	9.30
42 hrs. man labor @ 15c	6.30
42 hrs. horse labor @ 5c	2.10
Wear of sprayer	1.00
Total	$28.70

The test rows were of the variety Rural New Yorker No. 2. They were 586 ft. long by 33 in. wide. The yields were as follows:

Two sprayed rows, 436 lbs.=98.2 bu. per acre.
Middle unsprayed row, 66 lbs.=29.7 bu. per acre.
Gain, 68.5 bu. per acre.

Potatoes being worth 80 cents per bushel at time of digging the test rows (Oct. 15) the market value of the gain was $54.80. After subtracting the expense of spraying, $5.22 per acre, there remains *a net profit of $48.58 per acre.*

THE CHATEAUGAY EXPERIMENT.

Conducted by O. Smith & Son, Chateaugay, N. Y. Ten acres were sprayed four times using a one-horse, four-row "Iron Age" sprayer carrying one nozzle per row. Bordeaux of the 6-6-50 formula was used, the necessary water for its preparation being pumped by horse power from a stream at one side of the field. In the first and third sprayings arsenite of soda was applied with the bordeaux mixture to keep bugs under control. It was used at the rate of three quarts of the stock solution to 50 gallons of bordeaux. There were four check rows. These were treated with paris green twice, July 13 and 31. The writers did not see this experiment until digging time, but Mr. Smith reports that the sprayed rows outlived the unsprayed ones by about three weeks. He thinks the difference was due chiefly to early blight, which was prevented by the spraying.

The expense account contained the following items:

215 lbs. copper sulphate @ 8½c	$18.28
2 bbls. lime @ $1.10	2.20
80 lbs. sal soda @ 3c	2.40
20 lbs. white arsenic @ 8c	1.60
21½ hrs. man labor @ 15c	3.23
21½ hrs. horse labor @ 15c	3.22
Wear of sprayer	10.00
Total	$40.93

The test rows were dug Oct. 2. They were 1,507 ft. long by 37 in. wide and the potatoes were of the variety Uncle Sam. The yields were as follows:

Four sprayed rows, 3,502 lbs.=136.7 bu. per acre.

Two unsprayed rows, 1,340 lbs.=104.6 bu. per acre.

Gain, 32.1 bu. per acre.

There was no loss from rot.

On Oct. 2 the market price of potatoes at Chateaugay was 60 cents per bushel. At this price the gain of 32.1 bu. would have a value of $19.26. Deducting the expense of spraying, $4.09 per acre, there remains *a net profit of* $15.17 *per acre.*

THE GREENWICH EXPERIMENT.

Conducted by P. C. Billings, Greenwich, N. Y., who sprayed 8 acres of potatoes on three different dates, July 1, 13 and 31. The last spraying was a double one, i. e., the field was gone over twice. On Aug. 13 six rows each side of the check (three rows 931 ft. long) were given an additional spraying. Accordingly, the test rows were sprayed 5 times while the total expense, $35.58, covers the spraying of 8 acres 4 times and about 0.8 acre once. The sprayer used was a two-horse, 6-row "Aroostook" carrying one nozzle per row. In the first spraying, 4-4-50 bordeaux was used; in the others, 5-5-50 bordeaux. Paris green, one pound to 50 gallons, was used with the bordeaux in the first four sprayings. The check rows were treated with paris green three times—July 1, 13 and 31. There was no blight and scarcely any damage by flea beetles. The plants suffered only from tip burn and leaf hoppers. Mr. Billings states that there was no contrast between sprayed and unsprayed rows—it was apparent that the spraying was of no benefit.

The expense of spraying 8 acres 4 1/9 times was as follows:

154 lbs. copper sulphate @ 9c	$13.86
154 lbs. lime @ 1c	1.54
24 lbs. Paris green @ 32c	7.68
15 hrs. man labor @ 20c	3.00
15 hrs. labor for team @ 30c	4.50
Wear of sprayer	5.00
Total	$35.58

The test rows were of the variety Gold Coin. They were 931 ft. long by 3 ft. wide. The yields were as follows:

Two sprayed rows, 851 lbs.=110.6 bu. per acre.
Middle unsprayed row, 439 lbs.=114.1 bu. per acre.
Loss, 3.5 bu. per acre.

At 66 cts. per bu. 3.5 bu. have a value of $2.31. Adding to this the expense of 5 sprayings, $5.40 per acre, we have *a total loss of $7.71 per acre.*

THE GLENHEAD EXPERIMENT.

Conducted by G. T. Powell, Glenhead, N. Y. Fifteen acres of potatoes (in two lots) were sprayed five times. The sprayer used was a one-horse, four-row "Spramotor" sprayer carrying two nozzles per row. Arsenite of soda was used with the bordeaux in the first four sprayings. This was not necessary for bugs, but it was thought the poison might be of assistance in checking flea beetles which were very numerous. In one lot there was a strip of five check rows, in the other a strip of three. These were kept free from bugs by one application of paris green on June 23. During the drought in July there was a marked contrast between sprayed and unsprayed rows in both lots. There was no blight, but flea beetles were very numerous and injurious.

The expense account contained the following items:

400 lbs. copper sulphate @ 6½c	$26.00
2 bbls. lime @ $1.50	3.00
100 lbs. sal soda @ 1c	1.00
30 lbs. white arsenic @ 10c	3.00
60 hrs. man labor @ 20c	12.00
60 hrs. horse labor @ 10c	6.00
Wear of sprayer	5.00
Total	$56.00

The test rows gave the following yields:

West Field. Variety, Green Mountain. Rows 552 ft. x 30 in.
One sprayed row, 336 lbs.=176.7 bu. per acre.
One check row, 259 lbs.=136.2 bu. per acre.
Gain, 40.5 bu. per acre.

South Field. Variety, Gold Coin. Rows 450 ft. x 30 in.
One sprayed row, 215 lbs.=138.7 bu. per acre.
One check row, 243 lbs.=156.8 bu. per acre.
Loss, 18.1 bu. per acre.

Probably some mistake was made in the south field. Mr. Powell thinks that the stakes marking the check rows became misplaced. However, as definite proof of this is lacking it seems best not to reject the experiment. Averaging the two tests we have a gain of 12.4 bu., worth $9.92. Deducting the expense of spraying, $3.73, leaves *a net profit of $6.19 per acre.*

THE JAMESPORT EXPERIMENT.

Conducted by Henry A. Hallock, Jamesport, Long Island. Seventeen acres of potatoes were sprayed four times. The sprayer used was a one-horse, four-row Hudson sprayer carrying two nozzles per row. The dates of spraying were June 11, 17, 24 and July 10. The bordeaux was made by the 7-4-50 formula. The water required was pumped by a gasoline engine and hauled from 40 rods to one-half mile. In two sprayings arsenite of soda was used with the bordeaux at the rate of four quarts of the stock solution to 50 gallons of bordeaux mixture. There were four check rows. These received one application of paris green on June 11. The whole season there was no perceptible difference between sprayed and unsprayed rows. There was no blight, bugs did no damage and flea beetles were not troublesome. Apparently, there was nothing to spray for.

The expense account contained the following items:

500 lbs. copper sulphate @ 6½c	$32.50
2 bbls. lime @ $1.50	3.00
200 lbs. sal soda @ 2c	4.00
50 lbs. white arsenic @ 6½c	3.25
4 days man labor @ $2	8.00
4 days horse labor @ $1	4.00
Wear of sprayer	5.00
Total	$59.75

The test rows (variety, Green Mountain) were 690 feet long by three feet wide. They yielded as follows:

Two sprayed rows, 648 lbs.=113.6 bu. per acre.
Two check rows, 640 lbs.=112.2 bu. per acre.
Gain, 1.4 bu. per acre.

At the time of digging the test rows the market price of potatoes was 85 cents per bushel. At this price 1.4 bushels have a value of $1.19. Since the expense of spraying was $3.51 per acre the gain was not sufficient to pay expenses. There was *a loss of $2.32 per acre.*

THE SOUTHAMPTON EXPERIMENT.

Conducted by Lewis E. Downs, Southampton, Long Island. Fifty-six acres of potatoes were sprayed eight times with a two-horse, six-row "Aroostook" sprayer carrying one nozzle per row. The dates of spraying were June 17, 23, July 3, 10, 14, 20, 21 and 28. The bordeaux used was prepared by the formula, 6 lbs. copper sulphate in 50 gals. of water with sufficient lime added to satisfy the potassium ferrocyanide test. It was necessary to haul water about 40 rods. It was pumped by a windmill. In each spraying two quarts of the arsenite of soda stock solution were added to each 50 gallons of bordeaux. There were four unsprayed rows which were treated twice with paris green—on June 23 and July 5. There was no blight and not many flea beetles. Yet there was considerable contrast between sprayed and unsprayed rows during the last ten days of growth.

The expense of spraying 56 acres 8 times was as follows:

2,688 lbs. copper sulphate @ $6.17 per 100 lbs.	$165.65
2,688 lbs. lime @ 1c.	26.88
896 lbs. sal soda @ 1c.	8.96
224 lbs. white arsenic @ 6c.	13.44
182 hrs. man labor @ 20c.	36.40
182 hrs. labor for team @ 30c.	54.60
Wear of sprayer	12.00
Total	$317.93

The test rows were of the variety Carman No. 1. They were 1,000 feet long by 33 inches wide. The yields were as follows:

Two sprayed rows, 1,938 lbs.=254.8 bu. per acre.
Two check rows, 1,366 lbs.=180.3 bu. per acre.
Gain, 74.5 bu. per acre.

The market price of potatoes at digging time was 80 cents per bushel. Accordingly, the gain of 74.5 bu. had a value of $59.60. After deducting the expense of spraying $5.68 per acre there remains *a net profit of $53.92 per acre.*

SUMMARY OF BUSINESS EXPERIMENTS IN 1908.

TABLE XVIII.—SHOWING RESULTS OF BUSINESS EXPERIMENTS IN 1908.

Experiment.	Area sprayed.	Number of times sprayed.	Increase or decrease in yield per acre.	Total cost of spraying per acre	Cost per acre for each spraying.	Net profit or loss per acre.
	A		Bu.			
Southampton	56	8	74.5	$5.68	$0.71	$53.92
Ogdensburg	5.5	7	68.5	5.22	.75	48.58
Chateaugay	10	4	32.1	4.09	1.02	15.17
Batavia	13	5	28.3	4.03	.81	11.53
Sterling Station	9	5–6	20.4	5.18[8]	.96	7.06
Groton	8.75	5	20.1	7.31	1.46	5.65
Victor	10	2	18.7	1.93	.97	9.29
Glenhead	15	5	12.4	3.73	.75	6.19
Willink	20	3	7.2	2.78	.93	2.26
Elmira	19	4–5	2.5	2.45[9]	.54	—.83
Jamesport	17	4	1.4	3.51	.88	—2.32
Interlaken	10	4	— 3	3.79	.95	—5.50
Greenwich	8	4–5	— 3.5	5.40[10]	1.08	—7.71
E. Syracuse	4	5	—20.8	5.12	1.02	—23.84

[8] Average of 5 and 6 sprayings.
[9] Average of 4 and 5 sprayings.
[10] For 5 sprayings.

Average increase in yield per acre, 18.5 *bushels.*
Average net profit per acre, $8.53.

SUMMARY OF BUSINESS EXPERIMENTS, 1903-1908.

TABLE XIX.—SHOWING RESULTS OF BUSINESS EXPERIMENTS. 1903—1908.

Year.	Number of experiments.	Total area sprayed.	Average increase in yield per acre	Average total cost of spraying per acre.	Average cost per acre for each spraying.	Average net profit per acre.
		A.	Bu.			
1903	6	61.2	57	$4.98	$1.07	$23.47
1904	14	180	62.2	4.98	.93	24.86
1905	13	160.7	46.5	4.25	.98	20.04
1906	15	225.6	42.6	5.18	.985	13.89
1907	14	152.75	36.8	5.90	1.18	17.07
1908	14	200.25	18.5	4.30	.92	8.53

Average increase in yield, for six years, 43.8 *bu. per acre.*
Average net profit, for six years, $17.94 *per acre.*

VOLUNTEER EXPERIMENTS.

In 1904 the Station began collecting and recording the results of potato spraying experiments made by farmers in all parts of the State. As these experiments are carried out entirely by the farmers themselves we call them volunteer experiments. It is probable that, in some cases, the yields, expense of spraying and other data given for the volunteer experiments are not as accurate as are those given for the farmers' business experiments. Nevertheless, they are valuable. They supplement the regular business experiments. By bringing together the results of a large number of business experiments and volunteer experiments extending over several consecutive seasons the Station hopes to be able to answer definitely the question, Does it pay to spray potatoes in New York? We are under obligations to the many farmers who have assisted in this work and take this opportunity to express our appreciation of their services. The experiments are to be continued at least three years longer and it is hoped that we may continue to have the hearty coöperation of potato growers throughout the State. All who spray potatoes with bordeaux mixture are requested to leave a few rows unsprayed in order that it may be determined how much the yield is increased by spraying. The product of unsprayed and sprayed rows adjacent should be *weighed or measured* and the length of the rows measured so that the yields may be accurately determined. We cannot use experiments in which the yields have been only estimated. Neither can we use experiments in which the application of poison to the unsprayed rows has been neglected.

The following table shows the principal results of the eleven volunteer experiments reported in 1908. The marked decline in the number of volunteer experiments is probably due, in part, to the present lack of interest in spraying owing to the scarcity of blight during the past two seasons. There are also other reasons.

TABLE XX.—SHOWING RESULTS OF VOLUNTEER EXPERIMENTS IN 1908.

Experiment.	Location.	Name.	Area sprayed.	Times sprayed.	Yield per acre. Sprayed.		Yield per acre. Not sprayed.		Gain per acre due to spraying.		Cost per acre each spraying.	Price of potatoes.	Kind of sprayer
			A.		Bu.	lbs.	Bu.	lbs.	Bu.	lbs.	Cts.	Cts.	
1	Gainesville....	C. M. Dennis.....	12	4	187	15	63	55	123	20	....	60	6-row, 2-horse, Aroostook.
2	Lisbon........	S. Miller..........	2	5	226	7	103	9	122	58	60[11]	90	2-row, 1-horse, home-made.
3	West Rush...	T. E. Martin......	18	27	240	7	137	21	102	46	47	60	6-row, 1-horse, home-made.
4	West Rush...	D. S. Norris.......	4.5	4	59	51	4	43	55	8	....	70	6-row, 2-horse, Brown.
5	Bacon Hill....	E. W. Williams...	10	3	217	21	170	47	46	34	60	72	4-row, 1-horse, Aspinwall.
6	Canandaigua..	S. L. Van Voorhis.	10	3	100	22	72	40	27	42	....	55–60	6-row, 2-horse, home-made.
7	Peru.........	John Mannix......	2	2	82	48	58	4	24	44	77	50	5-gallon, compressed-air.
8	Memphis.....	M. Bowes.........	7	4	143	31	122	1	21	30	78	60	4-row, 1-horse, home-made.
9	Memphis.....	C. Parry..........	3.25	3	193	25	174	25	19	—	123	60	4-row, 1-horse, home-made.
10	Hornell......	W. Faulkner......	14	4	168	35	151	41	16	54	53	55	4-row, 2-horse, Watson.
11	Deer River...	DeV. Vrooman....	1.5	4	34	22	30	56	3	26	....	85	4-row 1-horse Hurst.

[11] For chemicals only,—does not include labor.

ADDITIONAL NOTES ON THE VOLUNTEER EXPERIMENTS IN 1908.

Experiment No. 1. Mr. Dennis states that the sprayed and unsprayed rows had an equal chance except as regards spraying. The unsprayed rows were not injured by bugs, yet they died four weeks earlier than the sprayed rows. The fact that a considerable number of rotten tubers were found at digging time indicates that late blight was a factor in this experiment. Flea beetles were not troublesome.

Experiment No. 2. It is not clear how spraying benefited the plants in this experiment. Although there was a marked contrast between sprayed and unsprayed rows Mr. Miller thinks there was no blight and the unsprayed rows were only slightly injured by bugs. Plant lice were plentiful.

Experiment No. 3. The total quantity of bordeaux used on 18 acres was 25,685 gallons, which is at the rate of 1,427 gallons per acre. A few rows which were double-sprayed each time, receiving bordeaux at the rate of 2,854 gallons per acre, outyielded the single-sprayed rows by 38 bu. per acre. Mr. Martin's experience shows that there is little danger of injuring potatoes by the most thorough spraying. Early and late blight were both absent and there was no rotting of the tubers. The unsprayed rows were well protected against bugs by several applications of paris green, but tip burn was prevalent and flea beetles and several other kinds of insects were numerous. The items of expense of spraying 18 acres were as follows:

20 cwt. copper sulphate @ $5.875	$117.50
23 bbls. Ohio Marblehead lime @ $1.05	24.15
28 days labor, man and team, @ $3	84.00
Incidentals	8.35
Total	$234.00

Experiment No. 4. There is some doubt about this experiment being a fair one. In the rush of haying the potatoes were neglected and the whole field was considerably injured

by bugs. Although the unsprayed rows were thoroughly poisoned the plants did not recover as promptly as on the sprayed rows. The sprayed rows outlived the unsprayed ones by about four weeks.

Experiment No. 5. Mr. Williams reports that there seemed to be no blight in this experiment. There was no rot, flea beetles were not troublesome and the unsprayed rows were not injured by bugs. The contrast between sprayed and unsprayed rows was not marked. The weather was very dry.

Experiment No. 6. The yields given are for unsorted potatoes.

Experiment No. 7. Mr. Mannix states that the unsprayed rows were considerably injured by some kind of blight; also, that some damage was done by "small green flies" [probably leaf hoppers] which were unaffected by paris green.

Experiment No. 8. The unsprayed rows died about a week earlier than the sprayed ones. The chief enemy fought was the flea beetle. It is doubtful if there was any blight in this experiment.

Experiment No. 9. Although the potatoes used for this experiment were the property of Mr. Charles Parry the experiment was, in reality, conducted by Mr. M. Bowes, who did the spraying and superintended the digging of the test rows.

Experiment No. 10. Mr. Faulkner states that there was no noticeable difference between sprayed and unsprayed rows. There was no blight on either.

Experiment No. 11. In this experiment the test rows were of the variety Early Harvest.

SUMMARY OF VOLUNTEER EXPERIMENTS, 1904-1908.

The following table shows the results obtained in the volunteer experiments during the past five years,—1904 to 1908 inclusive:

TABLE XXI.—SHOWING RESULTS OF VOLUNTEER EXPERIMENTS, 1904–1908

Year.	Number of experiments.	Total area sprayed.	Average gain per acre due to spraying.		Average market price per bushel of potatoes at digging time.
		A.	*Bu.*	*lbs.*	*Cts.*
1904	41	364	58	28	43.5
1905	50	407	59	32	57.0
1906	62	598	53	6	44.5
1907	24	264	30	28	58
1908	11	74	66	18	66

Average gain for 5 years (188 *experiments*) 50½ *bu. per acre.*

According to the above table the average gain per acre due to spraying, as reported by the volunteer experimenters, was larger in 1908 than in any preceding year. This is misleading. It indicates that spraying gave unusually good results in 1908, whereas exactly the opposite is true. In 1908 spraying was much *less* profitable than usual. It appears that the few experiments reported were the most successful ones. The truth of the matter is that many experimenters were ashamed to report the low yields which they obtained in 1908. It appears, also, that some consider their experiments of no value unless an increase in yield is obtained. This is a mistake. Whatever the results may be they are valuable and should be reported to the Station.

POTATO TROUBLES IN NEW YORK IN 1908.

In 1908 the potato crop in New York behaved strangely. In many cases even experienced potato growers were puzzled to account for the premature browning and drying of the potato foliage. The trouble known as tip burn, in which the tips and margins of the leaves become brown and dry, was almost universal and, in many fields, very severe. Many persons mistook this for blight. Both of the real blights, early blight and late blight, were scarce. The season was a dry one. Undoubtedly, the dry, hot weather was the chief cause of the tip burn. In many cases it was aggravated by flea beetles; in others, by leaf hoppers and other insects feeding on the foliage. Leaf hoppers were unusually abundant and flea beetles, as usual, were destructive in many fields. Bugs were not particularly troublesome.

Early blight (*Alternaria solani*) occurred in only a few localities and in a mild form.

Late blight and the rot which follows it appear to have been almost entirely absent. Although constantly on the lookout for it, the writers did not see a single specimen of *Phytophthora infestans* on potatoes during the past season. However, there is evidence that it occurred in at least three places in the State—Batavia, Gainesville and Clyde. Prof. H. H. Whetzel informs us that he has positive knowledge of its occurrence at Batavia. Mr. C. M. Dennis, of Gainesville, reports some loss from rot. While this rot may have been due to other causes the chances are decidedly in favor of it being due to Phytophthora. That the fungus appeared on potatoes at Clyde is proven by its occurrence there in a greenhouse on tomatoes which could have contracted the disease in but one way, viz., from potato plants beside which the young tomato plants stood previous to being transplanted into the greenhouse.[12]

[12] December 10, 1908, F. F. Miller, Clyde, N. Y., sent to the Station some greenhouse tomatoes affected with an unusual form of rot. After lying in a moist chamber for 24 hours some of the fruits developed conidiophores

DIRECTIONS FOR SPRAYING.[13]

In general, commence spraying when the plants are six to eight inches high and repeat the treatment at intervals of 10 to 14 days in order to keep the plants well covered with bordeaux throughout the season. During epidemics of blight it may be necessary to spray as often as once a week. Usually six applications will be required. The bordeaux should contain four pounds of copper sulphate to each 50 gallons in the first two sprayings and six pounds to 50 gallons in subsequent sprayings. Whenever bugs or flea beetles are plentiful add one to two pounds of paris green or two quarts of arsenite of soda stock solution to the quantity of bordeaux required to spray an acre.

Thoroughness of application is to be desired at all times, but is especially important when flea beetles are numerous or the weather favorable to blight. Using the same quantity of bordeaux, frequent light applications are likely to be more effective

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and conidia of *Phytophthora, infestans,* the potato blight fungus. It is not uncommon for this fungus to attack the foliage and fruit of tomatoes in the open, but its occurrence on tomatoes under glass seems to be rare. The fact that potatoes were so generally free from Phytophthora during the summer of 1908 lends additional interest to the case. Accordingly, one of the writers visited Clyde for the purpose of looking into it.

Mr. Miller stated that the tomato seed had been sown in June in a garden close beside a patch of potatoes. Here, the young tomato plants grew until some time in August when they were transplanted into the greenhouse. Mr. Miller did not notice whether the potatoes were affected with blight. Neither did he observe anything wrong with the tomato plants at the time of removing them to the greenhouse. In November some of the fruits began to rot. The trouble started in one corner of the greenhouse where the temperature was often lower than it should have been. The loss was small. yet there were always to be found a few rotting fruits. At the time of our visit (Dec. 15) only traces of the disease were to be found on the leaves, but affected fruits were common. Green fruits of all ages were attacked and, occasionally, fruits nearly ripe were affected. The fruits were variously marked with a conspicuous brown discoloration in the flesh. Many of the affected fruits showed no fungus on the surface; some, particularly those in an advanced stage of decay, bore molds of various kinds; while a few showed the fructification of Phytophthora which appeared as a delicate white mold.

If we assume that *P. infestans* produces no resting spores, the conclusion is inevitable that the tomatoes contracted the disease from the potatoes while growing beside them in the garden.

[13] Copied from Bulletin 290, p. 320. The experiences of the past season do not warrant any material alteration in the recommendations there made.

than heavier applications made at long intervals; e. g., when a horse sprayer carrying but one nozzle per row is used, it is better to go over the plants once a week than to make a double spraying once in two weeks. A good plan is to use one nozzle per row in the early sprayings and two nozzles per row in the later ones.

Those who wish to get along with three sprayings should postpone the first one until there is danger of injury from bugs or flea beetles and then spray thoroughly with bordeaux and poison. The other two sprayings should likewise be thorough and applied at such times as to keep the foliage protected as much as possible during the remainder of the season. Very satisfactory results may be obtained from three thorough sprayings.

A single spraying is better than none and will usually be profitable, but more are better. Spraying may prove highly profitable even though the blight is only partially prevented. It is unsafe to postpone spraying until blight appears. Except, perhaps, on small areas, it does not pay to apply poison alone for bugs. When it is necessary to fight insects use bordeaux mixture and poison together.

SPRAYING IN DRY SEASONS.

The past season being a very dry one over the entire State we have had exceptional opportunities for observing the effect of spraying potatoes in dry weather. An examination of Table XVIII shows that in nine of the fourteen business experiments spraying proved profitable while in the remaining five it was unprofitable. Notwithstanding dry weather and the absence of late blight the business experiments show an average increase in yield of 18.5 bu. per acre due to spraying and an average net profit of $8.53 per acre. Our observations convince us that it is unwise to neglect spraying in dry seasons. Even when there is no blight five or six sprayings should be made during the season. In dry weather the wounding of the leaves by bugs, flea beetles and other insects is more in-

jurious than in wet weather. Unless regular spraying is practiced the application of poison for bugs is likely to be neglected. Flea beetles flourish best in dry weather. It is an established fact that thorough spraying at the proper time will materially lessen the damage done by flea beetles. If flea beetles are not, at least partially, checked by spraying it is positive proof that the work has not been done properly. With us, the opinion is steadily growing that very few farmers spray thoroughly enough to secure the maximum profit from the operation. There seems to be little danger of overdoing the matter. The experience of T. E. Martin, West Rush, N. Y., is strong evidence on this point. Mr. Martin sprays with extreme thoroughness and invariably secures large increase in yield and large net profit.

A MYCOSPHÆRELLA WILT OF MELONS.[1*]

J. G. GROSSENBACHER.

SUMMARY.

The muskmelons, in one of the Experiment Station greenhouses, were much damaged during 1907-8 by an uncommon disease. The vines were parasitized by a fungus (Mycosphærella) shortly before the earliest melons were ripe. The disease was preceded, in both instances, by the attacks of a red spider, though in 1908 the damage by the spiders was but slight. The fungus is reported as causing a disease of several cucurbits in the fields of some parts of Delaware, but had never been recorded for this State. Since the Delaware reports differed in some respects from the observations made at this Station in 1907, nothing was published till further information could be obtained on the points of difference. The observations were repeated and extended in 1908.

The pathogeneity of the fungus and the relation of its two spore-forms are established. Inoculation experiments were effective, and, with but a few interesting exceptions, the spore-forms of the fungus always appeared successively on the inoculated vines.

The disease will probably not become injurious to field melons in western New York, though in greenhouses it may cause much trouble.

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[1] The more or less meaningless names in plant disease literature, as designations of both parasitic and non-parasitic diseases, have been the source of much annoyance to the writer, since the cause of a disease is not suggested by its name. The plea for such terms as wilt, blight, leaf-spot, canker and rot, is that the laymen can more readily understand them, but since only a very small fraction of plant disease literature is read by them, it seems unfair to the pathologist to compel him to use such vague terminology on their account. This need seems to be felt by a number of plant pathologists, as evidenced by some generic-name and disease-character combinations in some experiment station bulletins and other places, but not enough prominence has been given to the matter.

The suggestion is therefore made that the genus name of the infesting parasite be combined with some popular, descriptive term, as in this bulletin, or with the word *disease*, e.g. Sphæropsis canker of apple, Bacillus canker of apple, Tilletia smut of wheat, Ustilago smut of wheat, Fusarium wilt of flax, Bacillus wilt of cucurbits, Botrytis rot of lettuce, Sclerotinia rot of lettuce, and Thielavia root-rot of tobacco. Of course there are some popular names now in use, which are fairly distinctive and useful. The names of diseases caused by malnutrition and other physiological disorders may not so readily be made more concise until their causes are ascertained.

* A reprint of Technical Bulletin No. 9.

INTRODUCTION.

A striking disease of muskmelon (*Cucumis Melo*) made its appearance in one of the Station greenhouses devoted to melon culture during the summer of 1907. It was first noted by Mr. R. Wellington, Assistant Horticulturist, who was carrying on experiments in variety testing of muskmelons. Both the imperfect and ascosporic forms of fungous fructifications were found on the diseased vines, and pure cultures of them were used for inoculating healthy plants. The fungus proved to be the cause of the disease, and the associated fruits were shown to belong to one and the same fungus. This work was finished and written up before some published accounts by Mr. F. D. Chester[2] and Mr. C. O. Smith,[3] seemingly on the same disease, were found. The publication of the bulletin was stopped, for the time being, because it did not agree in all particulars with the articles cited; re-examination seemed necessary. In midsummer, 1908, the disease reappeared in the same greenhouse, thus affording an opportunity to test the former work.

Plan of this bulletin.—After an examination of Chester's and Smith's articles relating to this disease, with frequent quotations from the parts most essential, they are briefly compared with each other. The writer's observations and experiments of 1907–8 are then recorded, followed by the comparison of results. An attempt is made to correct the nomenclature of the fungus causing Mycosphærella wilt of melons. Finally, to clear up Mr. Smith's last paragraph, an appendix is added on the relation of the names of some cucurbit fungi.

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[2] Del. Exp. Sta. 5th Ann. Rpt. pp. 75–9 (1893), Newark, Del.; also *Bul. Torr. Bot. Club* **18**: 373–4 (1891), N. Y. Botanic Garden.

[3] Del. Exp. Sta. Bul. 70, (1905), Newark, Del.

RESUME OF CHESTER'S WORK[4] ON AN "ANTHRACNOSE OF THE WATERMELON."

During the autumn of 1890, a diseased watermelon vine was sent Mr. F. D. Chester at the Delaware Experiment Station from some point in that state, and he describes it as follows: "Where the vine stalk was yet green, it was found to be covered with elongated dark patches and irregular areas; tendrils, buds and leaf stalks were invariably black and dead, the leaves were covered with black blotches marked in many cases, by more or less distinct eccentric rides."[5] He recognized "pustules" on the leaf-spots as fruits of a Phyllosticta.

The vine was thrown upon a rubbish heap out of doors, where it was seemingly left until 1892 and then used again for inoculation purposes; though from another place[6] it seems that the material, used for the inoculation in 1892, must have been collected in 1891, because the disease is said to have been uncommonly destructive during 1891.[7] To quote: "The disease attacks leaf, leaf stalk, stem, tendrils, fruit buds and blossoms." The spots on the stems, which later become white in the center, are said not to cause any very serious damage.

It is further stated that "the fungus causing the above trouble is a member of the genus Phyllosticta, although from the character of the sporules, which are sometimes uniseptate and hyaline, it is questionable whether it might not, following Saccardo, be classed as an Ascochyta."[9] The following description and name are given: "*Phyllosticta citrullina,* n. sp. Spots circular, irregular, black, concentrically ridged, becoming confluent. Pycnidia amphigenous, brown, immersed, scarcely erumpent, membranaceous, lenticular 75–131 μ, average of many measurements 107 μ x 67 μ. Sporules 9–10.7 μ, average about 10 μ x 3.5 μ, generally continuous, sometimes uniseptate,

[4] Del. Exp. Sta. 5th Ann. Rpt. pp. 75–9, (1893).

[5] l. c., p. 75.

[6] Blight of watermelon vines—*Bul. Torr. Bot. Club* **18**: 373–4, (1891).

[7] l. c., p. 373.

[9] l. c., p. 374.

straight, slightly curved, ends obtuse, often biguttulate, hyaline. On leaves and other parts of watermelon."[10]

As stated before, the watermelon vine sent Mr. Chester in the autumn of 1890 is presumably used to inoculate young watermelon plants in 1892, according to the article in the annual report previously cited, but it seems more plausible to assume that the material used was collected in 1891, as suggested by the prevalence of the disease during that season. At any rate, during the early part of 1892 young watermelon plants were inoculated with spores obtained from an old diseased vine. Spots appeared on the leaves and later Phyllosticta pycnidia.

A Mycosphærella found.—Watermelon leaves, which had been preserved in press, were put into a moist chamber. In 10–14 days pycnidia of the same Phyllosticta appeared on the leaf-spots, and among them, perithecia of a Mycosphærella with spores measuring 14 x 5 μ.

Mr. Chester studied the disease in the field during 1892. On some fresh, characteristically diseased plants, he found also a "pink anthracnose on the same spots." The anthracnose is presumed to be *Glœosporium lagenarium* (Pass.) Sacc. et Roum.,[11] and is said "to agree with No. 2448 b. in Ellis' N. A. Fungi, which is there marked *C[olletotrichum] lagenarium* Pass. var. *follicolum* E. & E."

"To prove the relationship of the Colletotrichum to the disease under discussion, several young watermelon plants growing in the field were on July 28 thoroughly atomized with water containing in suspension Colletotrichum spores taken from watermelon rind. On August 3 the plants began to show the characteristic appearance of the disease and in less than one week were entirely dead. The check unatomized plants remained perfectly healthy."[12] Similar inoculations were re-

[10] l. c., p. 374.

[11] *Collectotrichum lagenarium* (Pass.) Sacc. et Roum. is said to be identical with *C. oligochætum* Cavara, given out as No. 99 in Briosi et Cavara's Funghi Parassiti, and not No. 100, as stated by Mr. Chester in a foot note on p. 78, Del. Exp. Sta. 5th Ann. Rpt. and by Dr. Halsted on p. 350, N. J. Exp. Stas. Rpt. for 1893, New Brunswick, N. J.

[12] Del. Exp. Sta. 5th Ann. Rpt. p. 78.

peated on large watermelon plants in the field, using "spores taken from the pinkish crust on watermelon rind. In two weeks many leaves showed characteristic spots, the vine stalk showed discolored zones here and there."

In order to obtain perithecia "numerous specimens of diseased rind" were collected and put into a wintering cage, but the Colletotrichum remained unchanged, and no perithecia appeared.

RESUME OF SMITH'S WORK[13] ON A "LEAF-SPOT ON CUCURBITS."

Mr. Smith notes the abundance of a "leaf-spot" of cucurbits on the leaves and fruits of squash and pumpkin, and "to a limited extent on the leaves of cucumber and cantaloupe." He thinks it identical with the watermelon leaf-spot disease caused by *Phyllosticta citrullina* Chester.[14] "On the leaves of various cucurbits, there appeared a leaf-spot which was quite similar on the different species. This appeared as dead spots from 0.5–1 inch (1–2 cm.) in diameter. . . . It is thought these spots may be associated with the melon anthracnose, *Colletotrichum lagenarium*, but no conclusion can be drawn that the two are connected in any way. The disease is also found on the vine. Plate I, E."[15] "The fungus on the stem forms a whitish area which is darkened with blackish specks, the pycnidia, Plate I, E."[16] "The spores are hyaline, oblong or oblong-elliptical, uniseptate bodies . . . vary somewhat in size and are not always septate and probably never all become so."[17] In pure cultures they were found to be mostly continu-

[13] Del. Exp. Sta. Bul. 70 (1905), Newark, Del.

[14] F. D. Chester, *Bul. Torr. Bot. Club* 18: 373–4 (1891), also Del. Exp. Sta., 5th Ann. Rpt. pp. 75–9.

[15] Del. Exp. Sta. Bul. 70, p. 4.

[16] Reproduced in this Bul. as fig. E of Plate III. The negative was borrowed from Del. Exp. Sta., through the kindness of Dr. Mel. T. Cook, Mycologist at that station.

[17] l. c., p. 5.

ous in their early stages, and biguttulate to sparsely septate, later.

Squash agar, potato agar, squash plugs and stems were used as culture media. "When growing on plugs or stems of squash, the mycelium is whitish and floccose; but with age changes to a dark color. Experience has shown that, on the rind, the pycnidia are formed most abundantly."[18]

"Seedlings of several varieties of squash, pumpkin, cantaloupe, watermelon and cucumber were inoculated with fresh spores during the winter and spring months. This was done not only with the fungus found growing on the individual host, but also cross inoculations were made on the other hosts of the cucurbits. The results were most satisfactory and conclusive *i. e.* that all these several fungi were really one and would grow on any of the cucurbits used in the experimental work."[19] "The *Ascochyta* form of the fungus, grown from the ascosporic stage, was found to cause the disease on cucurbits like the other *Ascochyta* grown from *Ascochyta* spores."[20] "Also a species of *Ascochyta,* resembling the one studied, grow[n] from an ascosporic or perfect stage, a species of *Sphaerella,* gave equally positive results in inoculation work."[21]

Mr. Smith expresses the view that since an Ascochyta differs from a Phyllosticta or Phoma only in its having septate spores, it may easily be mistaken for one of the continuous spored genera. He thinks it probable that *Phyllosticta orbicularis* E. & E.[22] "may be the same fungus."

A Mycosphærella associated with pycnidia.—A Mycosphærella was sometimes found associated with the Ascochyta *on squash stems.* "Attempts were made to germinate the ascospores . . . but only on one occasion were they seen to germinate. . . . Agar plates were poured, and these were inoculated at several points with a single perithecicum of the

[18] l. c., p. 5.
[19] l. c., p. 6.
[20] l. c., p. 10.
[21] l. c., p. 7.
[22] The N. Am. Phyllostictas (1900).

Sphaerella stage. . . . This experiment was repeated perhaps a dozen times always with the same result. The perithecia of the *Sphaerella* stage are darker and more carbonaceous than the pycnidia of the Ascochyta stage, so there was no danger in confusing the two. The fruit produced by this inoculation was always examined and on one occasion the *Sphaerella* and *Ascochyta* stage were found in the same colony on the agar plate. In fact, at least, two of the *Sphaerella* perithecia were found."[23]

Smith's article on the "Leaf-spot on Cucurbits" is closed with the following paragraph in small type: "*Sphaerella cucurbitacearum* (Schw). This fungus has been described in Saccardo's Sylloge under the genus *Laestadia*. At the close of his description he suggests in a doubtful manner that the spores are at length uniseptate. This I believe to be true and hence the species is a Sphaerella. This fungus seems to be much like one described by Fries as Sphaeria cucurbitacearum, but from his meagre description the identity is uncertain. I don't think there is the least question, but that the perfect stage, or squash *Sphaerella*, is identical with *Laestadia* cucurbitacearum (Schw) and should be, named Sphaerella cucurbitacearum (Schw) although in my text I have been satisfied to call the fungus *Sphaerella citrullina*."[24]

COMPARISON OF CHESTER'S AND SMITH'S WORK.

Both Chester and Smith seem to give undue prominence to the leaf-spot Phyllosticta, though the fungus on the stem is noted by Chester as forming "elongated dark patches" and Smith says it "forms a whitish area which is darkened with blackish specks, the pycnidia." The Mycosphærella-wilt fungus with its characteristic appearance and numerous fruiting bodies on the stem is given but secondary place by Smith and scarcely noticed at all by Chester. However, the latter's view seems to have changed during the progress of his work as shown by his change of names, first calling it, "Wilt of watermelon vines," and then "Anthracnose of the watermelon."

[23] l. c., p. 9.
[24] l. c., p. 10.

Chester tried to show that his Phyllosticta is the same as a certain Colletotrichum; he succeeds in showing that the "pink anthracnose" is parasitic on cucurbits, but fails to connect it with his Phyllosticta. Smith tried to connect his Ascochyta with Chester's *Phyllosticta citrullina* but records only conjectural evidence. The remarks by Chester on the relation of several anthracnoses, and his Phyllosticta, and the work and suggestions by Halsted,[25] on the former, need not be considered here, because no relation could be found between them and the Mycosphærella-wilt fungus.

The production of dead areas on leaves of a host, by pouring water laden with spores of a stem parasite of the same host on them, is no proof that the fungus normally parasitizes the leaves.[26] Especially is this true when the dead areas or spots produced fail to develop the fruits of the fungus used. In cases where the inoculated plants are enclosed in moist chambers, the results are yet more unreliable. When aerial parts of a host are at all susceptible to a certain fungous parasite, it seems probable that, under such conditions, all aerial tissues of that host, which have no special structural protection, would be more or less attacked, unless the required aeration for the fungus were prevented by the excessive moisture. Smith records no fruits on his artificially induced leaf spots; nor has the writer obtained pycnidia on leaves under any conditions, though dead areas developed from moist chamber infections; see Plate XI.

It seems that Chester either overlooked the fructifications of the Mycosphærella wilt on the vines, or it was not associated with his Phyllosticta leaf-spot, because he makes no mention of pycnidia or perithecia on vines; though, according to the writer's observations, to be given later, that is a constant character of the disease, both in the greenhouse and in the field. It appears more probable that Chester found the two fungi on the

[25] N. J. Exp. Stas. Rpt. (1893) pp. 347-56, New Brunswick, N. J.

[26] Miss C. M. Gibson's infection experiments with various rusts upholds such a view. Notes on infection experiments with various Uredineæ. *The New Phytologist* 3: 184–191 (1904).

same plants in Delaware, and that, since both are parasitic on the same host, they were confused with each other. Chester's characterization of the disease, and his finding a Mycosphærella seem to indicate that he also had Smith's fungus. From one of Smith's sentences, quoted on page 258, it seems possible that he had two fungi of the same type; on that assumption Chester may have had the other Mycosphærella. However, that suggestion is probably incorrect, though the quoted sentence is too ambiguous to be certain of its meaning.

The relation of Smith's ascosporic and pycnidial forms of the parasite is definitely shown, and sufficient scattered description of both is given, so that, with the aid of his photograph of a diseased squash stem (Plate IX, fig. E. of this bulletin) and a large quantity of squash-stem material, obtained from the Delaware Station in 1907, (collected and labeled by C. O. Smith) there is no doubt that Smith had the same fungus which is discussed in this publication, though his technical description of the imperfect form should be discarded, because it is only an amended form of Chester's description of *Phyllosticta citrullina.* As indicated before, *Phyllosticta citrullina* Chester seems only an accidental associate of the Mycosphærella-wilt fungus, and has never been found by the writer.

According to the evidence obtained, there is no reason to suppose that the Mycosphærella-wilt fungus is at all related to *Sphærella* (*Læstadia*) *Cucurbitacearum* (Schw) ? Cooke (see appendix), but it seems possible that *Sphæria Cucurbitacearum* Fries may be a Phoma[27] often found on the rind of squashes, etc. At any rate, spore measurements attached to that species by Saccardo,[28] and seemingly copied by Allescher,[29] correspond very nearly to this Phoma, the spores of which measure 7–10 μ. Whether or not this rind Phoma is a form of Cooke's *Sphærella* (*Læstadia*) *Cucurbitacearum* can not be determined with-

[27] Material of this type was obtained from the Mycologists at the Delaware Experiment Station, in 1907, which was collected and labeled Ascochyta, by C. O. Smith, Dec. 1903, at Newark.

[28] Sylloge Fungorum, III, p. 148.

[29] Rbh. Kr.—Flora, Vol. I, pt. 6, p. 284.

out examining all authentic herbarium material (if there is any) in connection with extended field observation and cultivation of the above Phoma.

OBSERVATIONS ON HERBARIUM MATERIAL[30] RECEIVED FROM THE DELAWARE EXPERIMENT STATION, 1907.

Squash vine material labeled Sphærella had rather scattered perithecia, but of the same type and structure as those of the Mycosphærella-wilt fungus. The measurements were: perithecia 110-170 μ, asci 45-55 x 7-10 μ, and spores 10-13 x 4 μ. Squash *stem* material *marked "Ascochyta citrullina"* was found to *contain mostly perithecia* of the Mycosphærella-wilt fungus, but also some of the *typical Diplodina pycnidia,* with spores hyaline, 9–15 μ long, uniseptate, more or less cylindrical and with or without constrictions at the septa. The Mycosphærella perithecium, ascus and spore characters were the same as those of the Mycosphærella-wilt fungus.

The cucurbit *leaf* specimens labeled *"Ascochyta citrullina* (Ches.) Smith" had pycnidia measuring 80–135 μ; the spores were elongate-ovoid, hyaline, continuous (about 3 per ct. being doubtfully septate) and measuring 7–9 x 3 μ. It seems a fairly typical Phyllosticta.

There were also a few good specimens marked "Colletotrichum," on leaf petioles of squash. The fruiting regions on these petioles were typical of that genus. The setæ were very conspicuous and the spores of the required type.

A considerable quantity of material marked "Ascochyta on fruit of squash, collected by C. O. Smith, December 1903, Newark, Delaware," may be described as follows: Pycnidia irregularly scattered on discolored rind or in concentric rings on nearly unchanged and normally colored rind. Both types are covered by the unbent palisade-like layer of the squash-fruit epidermis; only the blackish ostiola bend and break

[30] Collected mostly by C. O. Smith, and lent by the Mycologists of the Delaware Exp. Sta.

Photo. by M. J. Dorsey.

PLATE VII.—A DISEASED BUT STILL LIVING MUSKMELON VINE.

1, Leaves killed by red spiders; 2, diseased regions with dead cortical girdles having pycnidia, bordered by dying, oily green colored tissues.

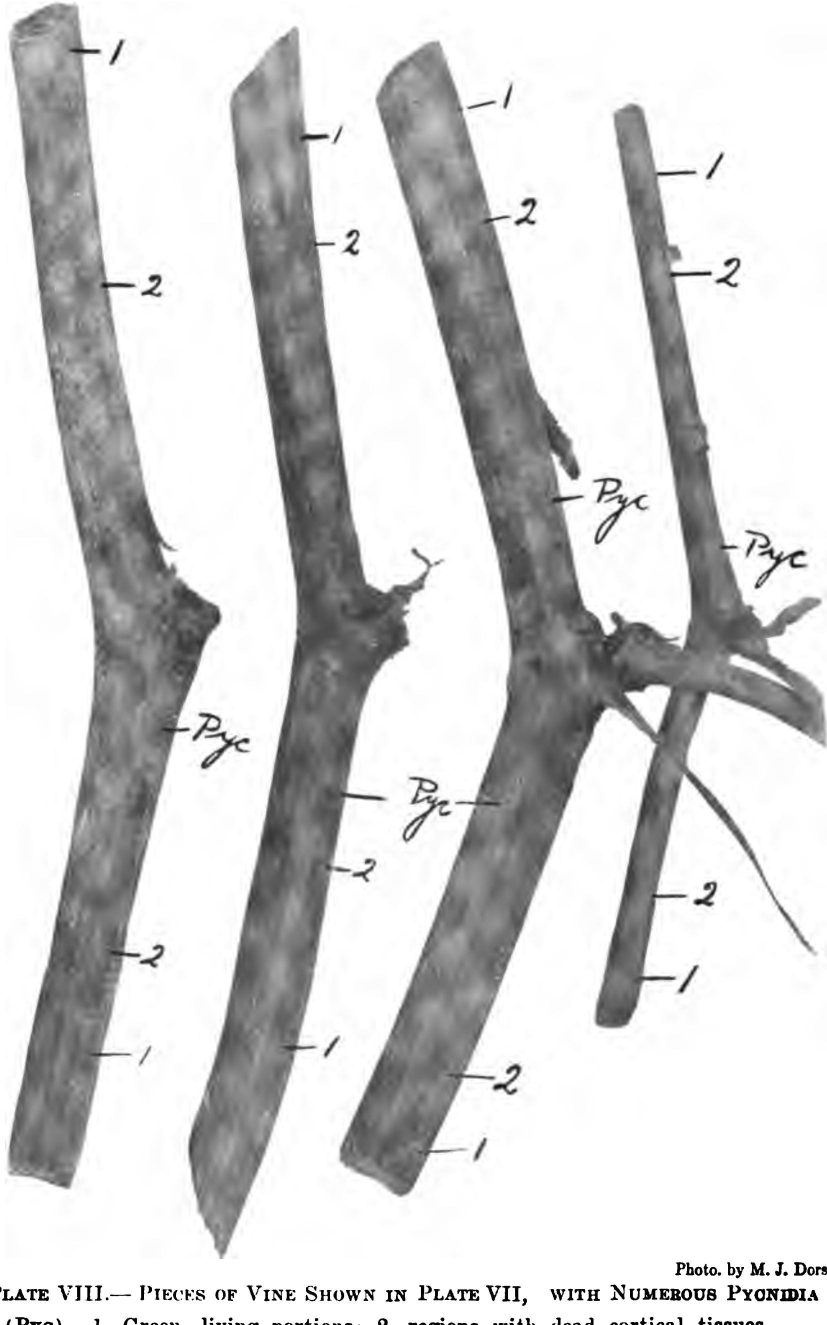

Photo. by M. J. Dorsey.

PLATE VIII.— PIECES OF VINE SHOWN IN PLATE VII, WITH NUMEROUS PYCNIDIA (PYC). 1, Green, living portions; 2, regions with dead cortical tissues.

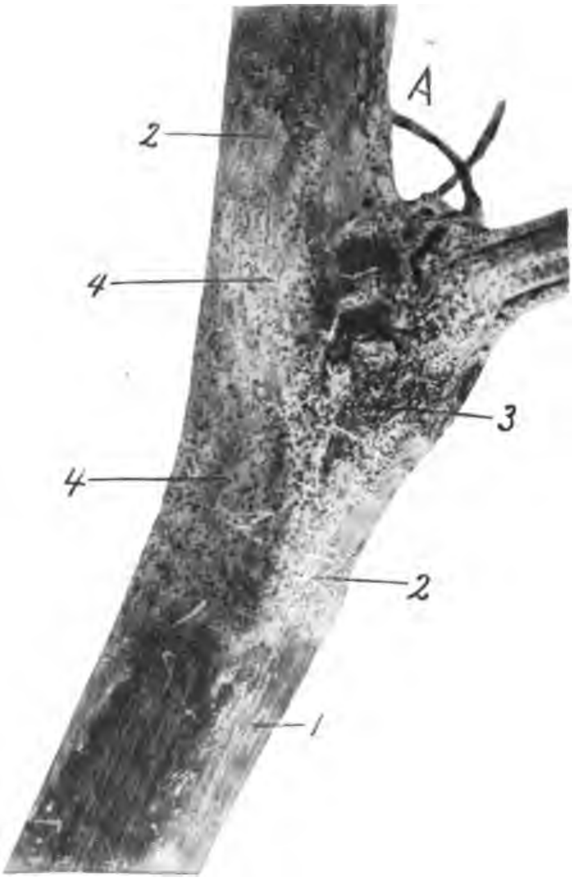

PLATE IX.

A, Portion of muskmelon vine with both pycnidia and perithecia; 1, Green, living portions; 2, dead, cortical regions, with pycnidia; 3, regions with perithecia.

Photo. by M. J. Dorsey.

"E, diseased squash stems, showing black dots, the pycnidia of the fungus."

From. Del. Ex. Sta. Bul. 70, Plate 1.

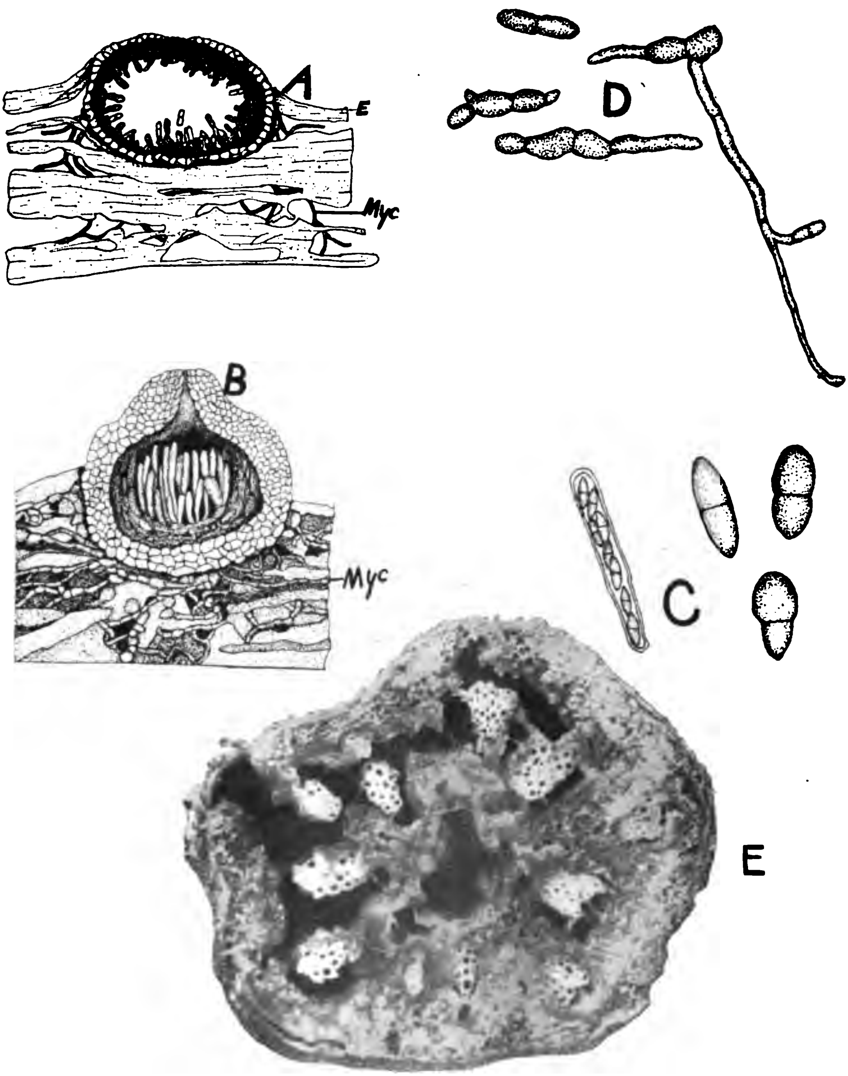

PLATE X.

A.— Section of pycnidium on muskmelon, showing mycelium (Myc.), epidermis of host (E) and spores.

B.— Section of a perithecium with immature asci. On muskmelon (cut slightly on the bias, walls are really a little thinner).

C.— An ascus with spores, and the three types of spores.

D.— Germinated and ungerminated pycnidiospores.

E.— Photograph of section of muskmelon vine, showing isolation of fibrovascular bundles, and some fungous-hyphal masses.

PLATE XI.—YOUNG MUSKMELON PLANT INOCULATED, IN MOIST CHAMBER, WITH PYCNIDIOSPORES BY POURING THEM ON THE LEAVES AND STEM.

X, Affected regions; no fruiting bodies developed on the leaves.

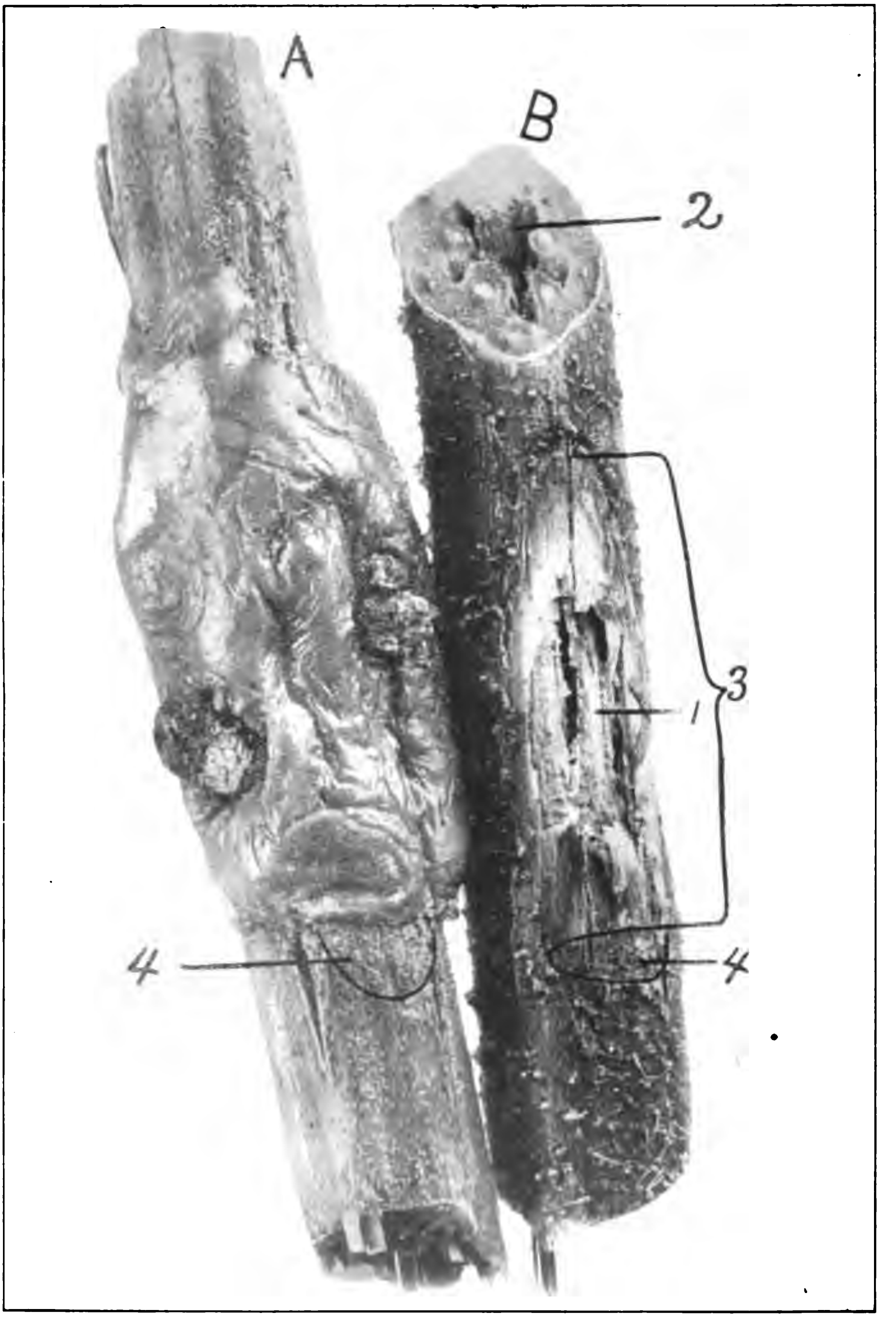

Photo. by F. E. Colburn.

PLATE XII.— SHORT PIECES OF INOCULATED PUMPKIN VINES.

A, Grafting wax still in place.
B, Wax removed from region 3: 1, wound through which mycelium entered hollow pith shown at 2; 4. dead portions of partially detached slivers, with perithecia.

through it. They measure 90–150 μ and are more or less depressed by the epidermis. The spores are oblong-ovoid, hyaline and mostly continuous, measuring 7–10 μ, the longest ones often being uniseptate.—Probably a Phoma as indicated before.

These, together with the greenhouse and field observations, to be given later, seem to show that Chester's *Phyllosticta citrullina* may be retained in the genus Phyllosticta, and that it at least should not be connected with Smith's "*Ascochyta on squash stems.*" However, nothing can be said about the real relation of *Phyllosticta citrullina* Ches. and Smith's "Ascochyta" on squash rind, except that according to the accepted scheme of classifying Deuteromycetæ they belong to different form genera, that on the rind being morphologically a Phoma.

The material marked "Ascochyta on squash stems" probably underwent some change *after* it was *examined* and *labeled,* since it had mostly perithecia of the Mycosphærella-wilt fungus. Some of the writer's observations also indicate that the pycnidia of this fungus may later change to perithecia by the development of asci from the interior of the basal portion of the fruiting body. In fact the mixture of these perithecia and pycnidia of the Mycosphærella-wilt type, under the label Ascochyta by its own author, indicates, not only that Smith's Ascochyta and Sphærella are connected, but also, that he had the fungus under discussion in this bulletin.

THE WRITER'S WORK OF 1907.

As intimated in the introduction of this bulletin, the work, on this disease-producing fungus, had been completed and the discussion put in type before any reference to it had been found elsewhere. The following is simply a scissors-and-paste report of the work of 1907; the present year's (1908) re-examination of the disease and of the fungus causing it, is briefly given afterwards.

DISEASE NOTICED.

The muskmelon vines in the Station greenhouse had practically reached their full growth before any trouble appeared.

Some of the first fruits were nearly ripe. The fungous disease was preceded by a rather severe attack of the red spider (*Tetranychus telarius*) upon the foliage, to such an extent, in fact, as to kill many leaves. The spider was similarly troublesome in an adjoining greenhouse in which cucumbers (*Cucumis sativus*) were grown. The blotched and dying leaves of cucumbers and melons first brought to the pathology laboratory by Mr. Wellington showed no traces of any fungous parasite. Yet the leaves continued turning yellow and dying in both greenhouses. The leaf petioles of these leaves slowly turned yellow and dried up, beginning at the dead leaf blade and gradually proceeding toward the vine axis from which the leaf grew. The spider was combatted by using ordinary hydrant water applied to the infested parts of the plants with a hose. It withstood that treatment but comparatively few days.

But it seems the trouble had only just begun. After the ravages of the spider had been gotten somewhat under control there appeared a marked difference between the recovering abilities of the plants in the cucumber and melon houses. The former soon showed fresh green foliage again, and, with the exception of the dead leaves, looked normal; while the latter seemed not to recover very rapidly. In fact, in a few cases, the dying petioles seemed to have a somewhat *water-logged* appearance at their junction with the vine. On a few nodes of this kind an *oily-green colored region* was evident from which a few drops of *resin-colored gum* had exuded. However as other things required attention at this time no more thought or time was given the melons till about a week later, when a few internodes, which had the nodal regions rather thickly specked with light-brown to dark-brown fruiting bodies of some fungus, were brought to the laboratory. On the internodes beyond the fruiting zones, the oily-green, water-logged character of the vine was very conspicuous; and this, with the resin-colored drops of gum which had exuded from them, seemed evidence that the condition of some nodes, as noted before, was the beginning of this disease.

INVESTIGATION OF DISEASE.

General description of the disease.—The greenhouse was visited at once and a striking difference found between the appearance of the melon plants then, and that of a week previous. Three or more plants were much wilted. Several of their lower nodes and some of their internodes were oily-green in color with or without gum exudation, while others had passed beyond that stage, having all the formerly oily-green regions turned either a dark and gummy or dry and grey color, depending upon the relative quantity of gum present and the extent of the cortical and sub-epidermal mycelial development that had taken place during the earlier stages of the disease. Upon looking the plants over more carefully it became very evident that a large percentage of them had some stage of the trouble at one or more of their nodal regions, more commonly on the lower nodes. Most of these infections were confined to small regions at the nodes, having seemingly originated in the axil of the leaf or in the crotch of a branch. All the smaller infections simply had the peculiar water-logged and oily-green condition; however, at those places where the disease had extended some distance above and below the nodes, there were generally numerous drops of gum and pycnidia present, especially on the lower nodal regions of the vine. See plates VII and VIII. In no case was an infection found to have started on an internode, but always either in the axil of a leaf or crotch of a branch. All infections observed at branchless nodes occurred at those having leaves which had been affected more or less by the red spider. At branching nodes the infection took place nearly exclusively in the crotch and not from the leaf axil; in some cases of crotch infection the leaf was normal and healthy.

Making pure cultures from diseased melon vines.—An extensive set of pure cultures was made from various regions of diseased muskmelon vines by taking bits of tissue under sterile conditions and transferring them to potato-agar tubes. All tubes containing tissue from the pith region remained sterile,

while those from the cortical region developed fungous mycelium in every case.

Preliminary inoculations in the greenhouse.—There being still some unaffected plants in the greenhouse, a few of them were used for preliminary inoculations. Two of the healthy vines were inoculated at two points each, by cutting a bit of the cortical tissue loose and inserting bits of mycelium from the potato-agar tubes, taking the usual precautions regarding sterile instruments. After sterilizing the scalpel carefully, two additional wounds were made. All were covered with grafting wax. Three days later both the inoculated vines were slightly wilted, and a week after the date of inoculation the infested vines had the characteristic appearance of the disease both above and below all four of the inoculated points; the usual oily-green, water-logged appearance of the affected regions farthest removed from the points of infection, and drops of gum on the nearer, darker colored parts. Next the wax, all the vines had an abundance of the yellowish brown to dark brown fruiting bodies. The checks, on a vine next the inoculated ones, had no trace of disease, and upon removing the wax from one, it was seen that a normal callus had formed over the wound.

The parasite may penetrate uninjured melon vines.—On August 2 a few inoculations were made in the greenhouse to test the penetration powers of the parasite. A healthy vine was selected and bits of mycelium from the formerly used set of pure cultures were placed on the uninjured surface of the main axis; three in crotches and one on an internode. August 8 the fungus had evidently penetrated at two of the inoculated points, for the usual water-logged appearance on both sides of the covering of grafting wax was present. About two weeks later (August 22) the disease had progressed some distance above and below the place of infection at both of the above noted cases, but the one at the node seemed to have penetrated deeper than that at the internode. The nodal infection looked darker and had the usual quantity of resin-like gum on its surface, while the one at the internode left the vine looking a little light-grey, with scarcely a trace of gum. But both had fruit-

ing bodies of the fungus, although the darker one had them standing much closer together. This test shows plainly that the fungus is able to penetrate the healthy uninjured surface of the muskmelon vine, and it also seems probable, from this experiment, that natural infection, occurring only at the nodes, is simply due to the fact that the spores were held at those points by drops of water sufficiently long for them to germinate and penetrate the tissue of the host, while the internodes afforded no such halting places for water.

Inoculation of melon vines in the garden.—It seemed rather important that inoculations should be tried out in the open and at a place where the disease had not, so far, appeared. The Director of the Station, Dr. W. H. Jordan, kindly consented to sacrifice some muskmelon vines growing in his garden, and on August 2 three vines were inoculated with mycelium from the same set of cultures as that used in the greenhouse on the same date; but the fungus was put in scalpel wounds instead of on uninjured surfaces as was done in the greenhouse inoculations. Each vine was inoculated at two points and covered with grafting wax. Three check inoculations were prepared; one on each of the vines. They were re-examined August 8 and it was found that only two of the inoculations had been effective. Upon removal of the grafting-wax coverings from the unaffected inoculated points, a large part of the cortical region of the covered portion was found to have been destroyed. The fungous hyphae were found present throughout the dry portions of the cortex, but the deeper lying green portions of the vine contained no hyphae which could be seen in freehand sections.

Microscopic characters of the pycnidial form.—The fruiting bodies, upon microscopic examination, proved to be pycnidia containing two-celled hyaline spores of the Diplodina type. A section shows the pycnidia originating in the region just under the epidermis through which they break, finally seeming nearly superficial. The pycnidia are slightly depressed globular, with pore-like ostiola, and measure 100—165 μ. See Plate X for

sketch. They originate from a very extensive, much branched brownish subepidermal mycelium and a much less profuse cortical mycelium. Both longitudinal and cross sections show the mycelium rather abundant in the cortical regions, but the deeper tissue reveals none except in cases where there is a wide gap in the sclerenchyma tissue, and even in such cases it does not progress very far between the bundles till some time after the maturity of the Diplodina spores. There were some cases noted in the greenhouse where the vines were killed about the time the spores were mature. Sections of such vines had abundant mycelium even in the pith region. A few days after such a vine had been killed by the disease a photograph was made of its cross section which clears up some points. See Plate X.

Discharge of pycnidiospores and how the disease was spread.—Upon examination of the pycnidia with a hand lens the darker ones are all seen to have papillate elevations in place of pore-like ostiola. By the addition of a little water to some unbroken pycnidia under a cover glass the microscope showed the papillate elevations to be masses of two-celled hyaline spores which had been forced out from the interior of the pycnidia. Shortly, the masses loosened somewhat showing individual spores more clearly, streamed off into the water, with a rather compact column of like spores continuing the streaming as long as three or four minutes. If one now recalls that this fungous disease was preceded by an attack of red spider and then followed by a long daily siege of heavy spraying with hydrant water, it will probably help explain the rapid spread of the disease after it had once started. And it also seems probable that an explanation of the position, on the vine, of all infections may be sought here. During spraying the pycnidia were moistened and those having mature spores would send forth numerous streams of spore masses which were at once carried away by the continuous stream of water and lodged on other vines, even at some distance beyond, down which they would be washed by the descending water. As the axils of leaves and the crotches of branches would natu-

rally retain certain quantities of this descending water, loaded with spores, suitable conditions for their germination were thus secured, from which infection could take place by the penetration of the mycelium into the axils or crotches of the vines. Of course, the saturated and warm atmosphere of the house was also very favorable by permitting drops of water to remain even whole days at such places.

Another spore form.—Around the nodal regions of some of the diseased vines are often darker fruiting bodies scattered among the brownish pycnidia, while a few regions were found having these black bodies alone. Only the older regions of diseased vines seemed to have the black fruiting bodies; for example, when any were present they were always most numerous about the point of infection, while farther removed from that point the pycnidia exclusively occupied the substratum (Plate IX). The vines having any of these darker fruiting bodies were either dead or in a dying condition when first observed. These black bodies are perithecia, containing subsessile to sessile, aparaphysate, cylindrical to clavate-cylindrical, eight-spored asci. They are very slightly imbedded in the host tissue as shown by hand sections, *i. e.*, they are evidently erumpent although finally nearly superficial. The perithecia are somewhat depressed-globular or inverted-top-shaped with their papillate apexes perforated by ostiola. They measure about 100–165 μ, and the asci 45–58 μ.

Collection and separation of the two types of fruiting bodies.—A large quantity of material was collected, from the diseased portions of muskmelon vines in the greenhouse. Some specimens were dead and dry; others were from vines in a very much wilted and dying condition, while a few were taken from green, rather vigorous looking plants. It was only on the former two types of material that perithecia could be found. By going over all the collected material it was separated into two groups, one containing only pycnidia and the other from few to mostly perithecia.

LABORATORY CULTURES OF THE FUNGUS (IN 1907).

Cell cultures of pycnidiospores.—A number of culture cells were prepared with small drops of sterile water and a few (perhaps from three to twenty) pycnidiospores were introduced, which were secured by putting some crushed pycnidia into a test tube about one-third full of sterile water. Twenty-four hours after planting nearly all were germinated. Some camera drawings on Plate X will help one get an idea of some of the stages as they occurred at this time. At the close of the second day there was some additional growth and branching, but the third day gave scarcely any growth although some differentiation had taken place. The short and sparsely branched mycelia had become septate and in many cases only a few of the terminal cells were filled with protoplasm. Most of the proximal cells seemed practically empty. Occasionally the two terminal cells on short lateral branches looked spore-like by being almost constricted off from the other cells of the mycelium. It has not been shown whether these bodies are secondary conidia or not; perhaps they are not. These cultures simply show that the pycnidiospores germinate in water and may be able to infect the host from twenty-four to thirty hours after a suitable environment has been attained. Transfers were made to potato-agar tubes to use for inoculations.

Cell cultures of ascospores.—Another set of fifteen culture cells were prepared like the above and the drops were each supplied with a crushed perithecium. Five infected drops were allowed to evaporate by holding the cover glass at some distance above a flame. A bit of agar was then put on the dried asci. All cultures were examined and those discarded which had no asci with spores. Both fusoid and constricted spores were often in the same drop, but in different asci. Two days after preparing the cultures many of the spores had germinated. There was practically no difference between the germination of these ascospores and the pycnidiospores. None of the fusoid spores were seen to germinate. The drops from three of the best cells were transferred to five potato-agar tubes. On the following day many of the germ tubes in the remaining culture cells

had become branched and septate. Only two of the agar cells had germinated spores. The others probably got too hot in drying over the flame. There was still no change in the fusoid spores. More transfers to potato-agar tubes were made.

FIELD INOCULATIONS (IN 1907).

Ascosporic and pycnidiosporic inoculation of muskmelon.— Two hills of muskmelons, which grew vigorous, healthy vines, having some full grown melon fruits attached, were selected in the garden, and on August 12 the plants of one hill were inoculated with pycnidiosporic and that of the other with ascosporic mycelium. The inoculating was done on the internodes by making tangential cuts into the cortex, inserting a bit of mycelium from potato-agar tubes and covering with grafting wax. Eight ascosporic and seven pycnidiosporic inoculations were made. Three checks were prepared for each group.

On August 24 seven of the ascosporic inoculations had produced the disease on the infected parts of the vine, showing the usual water-logged conditions of the green tissue farthest removed from the center of infection. The cortex nearer the inoculations was dead and dry, having a greyish color, and specked with dry drops of gum here and there. The general appearance of all but one of the plants was fresh and green, in fact, aside from the dead cortical girdles at the points of inoculation, the vines seemed normal. However, one of the vines looked rather flaccid and its leaves drooped slightly. Only four of the seven points inoculated with pycnidiosporic mycelium had become infected, producing a result just like the one described above; but two of these infections had a few pycnidia at the edges of the grafting wax.

The plants were re-examined on September 16. The two formerly wilted plants and one inoculated with pycnidiosporic mycelium had died while two of those infected with ascosporic mycelium were very much wilted. All diseased parts contained fruiting bodies of the fungus. Both pycnidia and perithecia were present on several infections of each hill, but the asci

were, with few exceptions, without spores. Those having spores had the characteristic appearance, and were of the same size as those used for the cultures. The three checks for each group were normal and uninjured throughout.

Inoculation of pumpkin vines with both mycelia.—To get some idea regarding the possible parasitism of this fungus for other species of the gourd family, pumpkin (*Cucurbita Pepo*) cucumber (*Cucumis sativus*), and watermelon (*Citrullus vulgaris*) plants were inoculated with both types of mycelia.

On August 25 a vigorous pumpkin plant was inoculated in the usual way on various parts of its vine. Three inoculations with pycnidiosporic and four with ascosporic mycelium were made. September 5 two of the pycnidiosporic and three of the ascosporic infections had rather narrow bands of slightly water-logged tissue on both sides of the wax covering, but no traces of gum flow could be seen. September 14 they were again examined. The wax was removed from those having shown no trace of the action of the parasite.

The wounds made during inoculation had healed normally. The narrow bands of water-logged tissue on those mentioned above had become no wider but had become dry. A few of the covers were removed and a dead girdle of cortical tissue was found extending about the width of the wax. The more or less hollow pith region of one of these had the inner surface of its tissues of a brownish color. Some transfers were made of the pith tissue from two other specimens, which had had waterlogged areas about the wax, and a fungous growth resulted which seemed indistinguishable from the one employed in the inoculations. On September 18 there were scattered perithecia on the three remaining infections around which some dead tissue could be seen. The hollow pith region (around the edges of which was some brown tissue containing hyphae of the fungus) as well as the perithecia, may be seen on Plate XII. Upon consulting the labels attached to the above inoculations two were found to have been infected with ascosporic and one with pycnidiosporic mycelium, on August 25. The perithecia were of the usual type, size and color. There were no pycnidia

present on any of the specimens. Many of the asci had their spores nonseptate; others, however, were septate.

Some peculiarities of pumpkin as a host.—Judging from the very slight injury done to the pumpkin vines there seems no doubt but that this host would be immune under ordinary conditions, though the presence of living mycelium in the naturally hollow pith region would probably have caused more trouble in course of time.

Perhaps the most striking peculiarity noted on this host is the entire absence of pycnidia from both ascosporic and pycnidiosporic infections. A large number of lighter-colored fruiting bodies farthest removed from the inoculations were carefully examined in the hope of their being pycnidia, but without exception, they were young perithecia in various stages of development. The substratum or host seems to be the determining factor as regards the production of perithecia and pycnidia and it would be of great interest to find some way of reproducing these conditions in pure cultures.

Inoculation of watermelon vines.—On August 31 inoculations with both types of mycelia on watermelon vines (*Citrullus vulgaris*), growing in the garden, were made. The infecting was done in the usual way by wounding the internodes of the vine with a sterile scalpel. Two vines were inoculated at two points each with pycnidiosporic mycelium and two other plants with ascosporic mycelium; one at three points and the other at two. Two checks were prepared for the group of four and three checks for the group of five. On September 5 all inoculations of both groups had taken and one vine in each group had wilted. Pycnidia were present on vines of both groups. They were the size and character of the Diplodina before mentioned; the spores also agreed in both size, form and color. Eleven days later, September 16, some of the dead and dying vines were collected. Specimens from both types of inoculation contained perithecia and pycnidia. The checks were all without any traces of disease.

Comparison of susceptibility of muskmelon and watermelon.—The parasite did more active and destructive work on water-

melon than on muskmelon. The watermelon vines were less resistant and the pycnidia were mature a day or two sooner than on muskmelon. The watermelon vines were healthy and bearing many but small fruits; however, the vines were rather short and slender. Possibly the severity of the attack was in some measure due to the rather slight vines. It would perhaps be of interest to grow some watermelons in a greenhouse with the fungus present, for it seems probable that they would be naturally parasitized by this fungus.

Inoculation of cucumber vines.—On August 31, both types of mycelia were used to inoculate some mature but still vigorous cucumber vines. Three pycnidiosporic and five ascosporic inoculations were made, also two checks for each group. The method was the usual one; tangential cuts were made with a sterile scalpel into the cortex of the vines, and bits of mycelium inserted and covered with grafting wax.

September 5 there was no change either on the infected or the check vines. September 14 some of the wax coverings were removed and found to have the cortex of the vines uninjured by the introduced fungus. A normal callus had formed over the wound. All inoculated bits of vines were examined microscopically and cultures were tried from the interior but neither method revealed a fungus.

Why is the cucumber vine immune?—Since the cucumber and muskmelon are species of the same genus (*Cucumis*) it was to be expected that the cucumber would also be parasitized. As there were no younger cucumber plants accessible, their resistance could not be tested. It seems very strange that this species of Cucumis should be immune while a species of a related genus is very susceptible. The similarity of stem structure of *Cucumis Melo* and *Cucumis sativus* is evidence that the difference in the susceptibility of the two species is not due to their structural differences but rather to differences in the cell sap or cell constituents.[31]

[31] Parasites, of course, differ in their reactions to the same groups of host species, as shown by G. M. Reed's work, Infection experiments with the mildew on Cucurbits, *Erysiphe cichoracearum* DC. Trans. Wis. Acad. Sc., Arts, and Letters **15**: 527–47 (1907), Madison, Wis.

INOCULATION OF POTTED MUSKMELON PLANTS.

Inoculation of young muskmelon plants by pouring spores, suspended in water, over them.—Potted muskmelon plants which had been planted for this experiment (the Emerald Gem variety), had now attained to a size sufficient for use in inoculations in a moist chamber. They were from six to ten inches long, having from four to seven foliage leaves developed. September 2 six of them were put in a large cubical moist chamber, in the greenhouse, having its sides and top of glass and its floor covered with a layer of Sphagnum moss. The plants, floor and sides of the moist chamber were thoroughly sprayed with hydrant water. A quantity of crushed pycnidia was put in each of six test tubes about half full of sterile water and one tube slowly emptied on the vine and leaves of each of the plants. Also two of the potted plants were placed under separate bell jars in the laboratory. A tube of sterile water containing a large quantity of pycnidiospores was poured over one and the other left for a check.

September 5 there were a number of leaves, in both the cubical moist chamber and under the bell jar, having brownish areas where the tissue was dead. Sections of the leaves were made and found to contain mycelium threading through all parts of the affected regions. Many of the flower buds and leaf axils had traces of the water-logged tissue noted as a symptom of this disease. On September 7 most of the leaves of the inoculated plant under the bell jar were wilted and drooping. It was photographed and many of the above facts may be seen by referring to Plate XI. The check under the other bell jar remained healthy.

September 22 only four of the six plants which were placed in the large cubical moist chamber had been practically killed. The other two had a few dead regions on some of their leaves but had seemingly recovered. Two of the dead plants had a few scattered pycnidia on the vines but none on the leaves.

Inoculation with pycnidiospores by wounding the host.—September 6, four of the healthy potted plants were inoculated with

pycnidiospores by placing the spores in a wound and covering with grafting wax. The pycnidia for this were carefully picked with a sterile needle and crushed in small drops of sterile water on sterile slides. The drop containing the spores was then carefully drawn off into the wound. One check was prepared. September 18, three of the plants were very much wilted and the fourth had only a small region next the wax which was water-logged. The three dying plants had numerous pycnidia, but no perithecia, on the diseased parts. On September 26 the fourth inoculated plant had wilted and was dying. Pycnidia were also present. October 7 perithecia could be found on two of the four. The check was still in good condition. On September 25 the two remaining potted plants were inoculated with ascosporic mycelium which had been obtained from Van Tieghem cell cultures, September 18. October 7 both vines were wilting and dying, and there were pycinidia present near each point of inoculation.

The relation of the two types of fructification.—The pure cultures from the ascospores and the pycnidiospores, used in the foregoing inoculations, give strong evidence that the Diplodina pycnidia are the fruiting bodies of the Mycosphærella, coming later. There seems no question but that these two types of fruiting bodies are simply stages in the life cycle of the same fungus. With but one exception, inoculation with ascoporic mycelium produced the Diplodina pycnidia before any perithecia were produced. The exception has but little weight here because on that host (pumpkin) the pycnidiosporic inoculation produced only perithecia also.

SPORES, IN CULTURE, NOT TYPICAL.

On November 12, transfers of both types of mycelia were made to tubes of alfalfa stems. The mycelial growth of both was similar and vigorous, turning darker with age. November 26, numerous typical Diplodina pycnidia were present in all the tubes. No difference could be detected between those from the ascosporic, and pycnidiosporic mycelia; they were somewhat undersized from both. The spores were also small,

mostly 9–12 μ. Only about half of them were septate. The shorter ones were either continuous or doubtfully septate.

RE-EXAMINATION OF THE MYCOSPHÆRELLA WILT OF MELONS IN 1908.

Introduction.—Both the red spider and the Mycosphærella wilt reappeared on muskmelons in the same greenhouse in 1908. The soil used on the melon benches in 1907 was removed in September, exposed to the weather, but returned to the same benches in March, 1908. The house was thoroughly fumigated with hydrocyanic acid gas before the plants were introduced. They were benched about two months earlier than in 1907.

The appearance of other parasitic fungi.—When the melons were about two-thirds grown a Coremium-like fungus was found attacking two vines a few inches from the ground and destroying the cortical tissues on a short region of the stem. The fungus produced large quantities of spores but failed to infect other plants. The two affected plants neither wilted nor evidenced harmful effects, yet each had a girdle of destroyed cortical tissues. A Sclerotinia, probably *Sclerotinia Libertiana* Fckl., proved a more virulent parasite. The parasitized vines had an oily-green, water-logged appearance, and occasionally a few drops of exuded, resin-colored gum. By the presence of fluffy, aerial mycelium, later forming sclerotia, and by the entire absence of any fruiting bodies on the affected stems, it is easily distinguished from Mycosphærella wilt, though it may cause partial wilting of the vines. Comparatively little damage was done by this fungus.

Occurrence of the red spider.—The red spider became evident shortly after the appearance of the Sclerotinia; it was sprayed with water as in the previous season and readily controlled, though some leaves turned yellow.

Reappearance of the Mycosphærella wilt.—About the time the first melon fruits had attained full size, the Mycosphærella wilt reappeared; being about a month earlier than in 1907. On June 23, three vines were found to have some of their lower

nodal regions affected. The hardened drops of gum about the dry, greyish nodes with densely scattered pycnidia, and the oily-green, water-logged appearance of the stems below and above the nodes, was a repetition of its occurrence in 1907. Again, on some diseased vines the older affected regions (the parts having fruits of the fungus) were of rather dark color and had larger quantities of exuded gum. Numerous Diplodina pycnidia were present on all the affected nodal regions, and, on a few of the oldest infections, Mycosphærella perithecia. A week after the disease was first noted, more than a dozen vines had become infected at several nodes each.

No Phyllosticta on the leaves.—A thorough search was made for Chester's Phyllosticta on the leaves of the infected vines but it was not found, though, at many of the diseased nodes, the leaves died about the time the water-logged condition first was observed. (Probably due to the red spider.)

The disease more conspicuous than in 1907.—On July 20, at least one-third of the vines were either badly wilted or dead. The disease was more rapid and destructive than in 1907, and possibly more conspicuous because the red spider had injured and killed fewer leaves before the fungus appeared. The fuller descriptions of 1907 are referred to for details regarding the fructifications and appearance of the disease.

Re-isolation of the fungus in 1908.—In order to obtain fresh, vigorous cultures for inoculation experiments, numerous tissue transfers from the interior of diseased, water-logged portions of muskmelon vines were made to tubes of potato-agar. Carefully picked perithecia and pycnidia[8] were crushed in separate drops of sterile water, and under sterile conditions, transferred to separate sets of 25 Van Tieghem cells. In about twenty hours, probably 95 per ct. of the spores, in both the ascosporic and pycnidiosporic cells, had germinated. Many transfers to tubes of potato-agar were made from both types of germinated spores. The resulting mycelial growths seemed identical in all tubes. An inoculation test on muskmelon vines proved both alike parasitic and followed by like pycnidia and perithecia.

[8] It is a comparatively easy matter to distinguish between pycnidia and perithecia with a hand lens.

MYCELIAL INOCULATIONS OF SOME OTHER SPECIES OF CUCURBITS.

Several other cucurbits were specially grown (1908) to be used in pathogeneity tests. Young potato-agar cultures were used as sources of the fungous mycelium. The stems of the plants were wounded by tangential cuts and the mycelium was placed under the sliver. About half of the inoculations were covered with grafting wax and the others were left without protection. (Both methods were effective to about the same degree.) In most cases but one set of inoculations was made before bacterial contamination of the stock cultures became evident, as shown by the inability of the fungous mycelium to parasitize *Cucumis Melo*. The following is a brief summary of the results:

1. *Cucumis sativus* (Cucumber). Twelve inoculations were made as stated above. No visible effect was produced on the host and no fungous fruits were developed.

2. *Cucumis Anguria* (West Indian Gherkin). Ten inoculations were made. The wounds healed normally and no fungous fruits resulted.

3. *Cucurbita maxima* (Boston Marrow Squash). Eight inoculations were made on the vines and six on the fruits. The wounds healed normally. However, some perithecia with spores and a few pycnidia appeared on the dead slivers of the vines, but the squash-fruits seemed neither affected by such inoculations, nor developed any fungous fructifications.

4. *Cucurbita Pepo* (Pumpkin). There were eight inoculations made on the vines and seven on fruits, but no visible effects were produced on either, yet, a few of the dead slivers (resulting from the tangential cut preceding inoculation) on the vines developed typical perithecia with spores. No pycnidia could be found.

5. *Lagenaria vulgaris* (Sugar Trough Gourd). Forty inoculations were made on fruits and vines, with no apparent affect upon the host, but a few fully developed perithecia with spores were found on two dead vine-slivers.

6. *Luffa cylindrica* (Dish-cloth Gourd). Eight inoculations were made on the vines and five on fruits. No effect resulted on the vine but a few immature or sterile fruiting bodies occured on a dead vine-sliver. Portions of two gourd fruits were decayed and contained mature Diplodina pycnidia with spores.

Though it is desirable to have these inoculations repeated, they are an indication that none of these cucurbits are normally susceptible.[32] The fungus had no evident effect on any but *Luffa cylindrica,* though it was able to vegetate and fruit on some dead vine-slivers of other species.

Development of perithecia on the vines of naturally immune cucurbits.—It is unusual to find the natural sequence of spore-forms interrupted or to have one entirely omitted. Spores of the perfect and imperfect forms of a fungus generally follow each other in some definite order, whether the perfect form be an oospore, zygospore, teleutospore or ascospore. But at present, there are some well known exceptions in each of the above groups: some producing but one known type of spore.

There has been some notable work done, on some members of the "oosporic group," in artifically causing either type of spore to be produced by means of certain culture media and environment,[33] and on species of the "zygosporic group," by showing them to be heterothalic and therefore requiring two sexually unlike individuals of a species for the production of zygospores.[34]

[32] Some recent infection experiments by Dr. G. M. Reed give a comprehensive grouping of cucurbits and other plants in regard to their susceptibility to some parasitic fungi. Infection experiments with *Erysiphe cichoracearum* DC. Bul. 250, Univ. of Wis. (Science Series Vol. 3, No. 8. pp. 337–416), Madison, Wis.

[33] G. Klebs, Zur Physiologie der Fortpflanzung einiger Pilze, *Jahrb. f. Wiss. Bot.* **33**: 513 (1899), and also **35**: 80 (1900). G. Klebs, Willkürliche Entwickelungsänderungen bei Planzen, Jena 1903.

[34] A. F. Blakeslee, Zygospore formation a sexual process. *Science* N. S. **19**: 864–6 (1904) Lancaster, Pa. Sexual reproduction in the Mucorineæ. *Proc. Am. Acad.* **40**: 205–319 (1904), Boston, Mass. Zygospores and sexual starins in the common bread mould, *Rhizopus nigricans*. *Science* N. S. **24**: 118–122 (1906).

Whether the type of spores produced by the members of the teleutosporic and ascosporic groups may be controlled by either or both of the above methods is yet an open question. In case of the Mycosphærella-wilt fungus, on its normal hosts, the environment seems the important factor. The cortical tissues have been thoroughly permeated by the mycelium and killed when the pycnidia are produced; and generally these tissues are comparatively dry before the perithecia appear. Some of the latter conditions are found on the dead pumpkin-vine slivers, though others are absent. In this case it seems plausible to assume that conditions inhibiting further vegetative development of the fungus on diseased muskmelon vines, as well as the "adverse" environment of mycelium, introduced under a sliver of a pumpkin vine or similar host, tend to cause the production of the "perfect" spore-form. The dry condition of the substratum *seems the* important factor in the formation of the "perfect" spore-form. Lakon concludes that transpiration is the greatest single factor in causing the development of the fructification of *Coprinus plicatilis,* other factors being of importance only in so far as they accelerate transpiration. But in an *Anhang* to his paper he states that his fungus would not fruit on *Vicia Faba*—decoction agar though it did when stems of *Vicia Faba* were placed in agar-agar.[35]

Some of the above observations on immune cucurbits and the pumpkin inoculations of 1907 (Plate XII) seem to indicate that certain conditions of environment may produce ascospores and be adverse to or check the formation of pycnidiospores.

INOCULATION OF MUSKMELON AND WATERMELON.

Mycelial inoculations.—About fifty inoculations were made in the field on each of both watermelon and muskmelon vines, which were large and vigorous. The mycelium, taken from a fresh potato-agar culture, was introduced under a vine-sliver which had been made by means of a tangential cut with a sterile scalpel. Half of the infections were covered with graft-

[35] G. B. Lakon, Die Bedingungen der Fruchtkörperbildung bei Coprinus. *Ann. Myc.* 5: 155–176 (1907), Berlin.

ing wax and the others left uncovered. They were all effective except four of the covered ones on muskmelon. Both pycnidia and perithecia occurred on these inoculations.

The stock cultures were retransferred to tubes of potato-agar. A few days later another, but smaller, set of inoculations was made. Only a few of the uncovered ones were effective and produced pycnidia. The cultures were found to be contaminated with a bacillus, which after losing its motility developed great numbers of dumb-bell-shaped and globular, brownish involution forms.

Ascosporic and pycnidiosporic inoculations.—From freshly collected muskmelon vines (growing in the greenhouse) large quantities of pycnidiospores were obtained, suspended in sterilized water, and transferred to the plants to be inoculated, by means of a sterile pipette.

The vines from one muskmelon hill and one watermelon hill were inoculated. The uninjured nodes of each species were infected with spores. Every inoculated node was covered with wet, sterilized absorbent cotton. Equal numbers of similar inoculations were made on both hosts, except that the nodes were punctured with a sterile forceps before the spores were transferred to them.

The cotton on all nodes was resaturated with sterile water one and a half hours after inoculation. The following morning, fifteen hours after inoculation, sterile water was again applied. All but three of the cotton wads were still moist. Six hours later more water was added.

Only one of the forty inoculations became injurious and produced fruits of the fungus: on a punctured node of muskmelon.

Equal numbers of similar inoculations were made on other plants of the same hosts, using ascospores. The cotton was remoistened but once: three hours after inoculation. Neither the injured nor uninjured nodes were parasitized. The spore inoculations of 1907 (p. 278) no doubt were effective because they were put in direct contact with the inner host tissues and were provided with both moisture and nutritive matter under the protecting wax.

A probable reason why the disease has not been found in the fields of western New York.—The almost complete failure of these spore inoculations, in the field, suggests a reason why the parasite has not been observed in the fields of this vicinity. It seems that the very moist, warm environment of the greenhouse is essential for the infection and development of this fungus and that field conditions are preventive.

REMARKS ON THE WORK OF 1907–1908; PREVENTIVE MEASURES.

As may be seen from this condensed summary of the work of 1908, excepting some additions and extensions, it is only a repetition of that recorded for 1907. In general, there is no difference between the two seasons' observations: the characters of the disease, as well as the two spore-forms of the fungus, were the same throughout.

It seems probable that the spores of this fungus are not killed by exposing infested soil to weathering conditions of winter, nor by fumigation with hydrocyanic acid gas, and, that earlier planting of melons fails to prevent an attack. However, it seems that this disease may readily be prevented in the greenhouse by spraying thoroughly with bordeaux mixture when the plants are about half grown (*i. e.,* before the disease appears), and repeating often enough to keep them covered with the spray. An unsuccessful spraying experiment, on watermelons, is recorded by Mr. Chester,[36] but the failure very probably was due to the fact that the disease had become evident before the spray was applied.— When the plants are sprayed with water the house should have good ventilation.

CONCLUSIONS REGARDING THE NAMES OF THE FUNGUS.

From Chester's characterization of the disease it appears possible that he also had the fungus discussed in this bulletin, on the same vines on which he found his Phyllosticta, though he mentions no fruits of it as occurring on the vines. Smith unquestionably had the Mycosphærella-wilt fungus, but since

[36] Del. Exp. Sta. 5th Ann. Rpt., p. 79.

it has not been found on the leaves (the fruiting bodies therefore not occurring in spots), there is no reason to put the pycnidial form in Ascochyta. For these reasons it is retained in Diplodina. Smith having transferred the species name of Chester's Phyllosticta to both spore-forms, it is used, though his description of the imperfect form must be discarded, and his characterization of the perithecial form is very general, scattered and incomplete.

TECHNICAL DESCRIPTION OF THE MYCOSPHÆRELLA-WILT FUNGUS.

Mycosphærella citrullina (C. O. Sm.) Grossenbacher.

Sphærella citrullina C. O. Smith, Delaware Experiment Station Bulletin 70 (1905), Newark, Del.

The perithecia are roughish, dark-brown to black, depressed-globular to inverted-top-shaped, with, generally, papillate ostiola, simple, densely scattered, erumpent and finally almost superficial, 100–165 μ. The asci are cylindrical to clavate-cylindrical, aparaphysate, sessile to subsessile, 45–58 x 7–10 μ. Spores, mostly uniseriate, two-celled, hyaline, oblong-fusoid to fusoid, with one or both cells bluntly ovoid and therefore constricted at the septum (distal cell often larger) or not constricted.

On the vines of *Cucumis Melo* and probably *Citrullus vulgaris.*

Diplodina citrullina (C. O. Sm.) Grossenbacher.

Ascochyta citrullina C. O. Smith, Delaware Experiment Station Bulletin 70 (1905), Newark, Del.

The pycnidia are slightly depressed-globular, with pore-like ostiola, and of light-brown to dark-brown color; subepidermal to cortical erumpent and simple, 100–165 μ. Spores, hyaline, two-celled, more or less cylindrical, with rounded or tapering ends. They may or may not be straight or constricted at the septa, 10–18 x 3–5 μ.

On the vines of *Cucumis Melo* and probably *Citrullus vulgaris.*

APPENDIX.

THE IMPLICATED MYCOSPHÆRELLA (LÆSTADIA) CUCURBITACEARUM (SCHW.) ? CKE.

The confusion wrought by Mr. Smith's last paragraph (p. 259 of this discussion) brings out some things of interest. Though the fungus or fungi involved seem not to be the same as the parasite discussed in this article, it is thought advisable to make an attempt at clearing up the difficulty. He has simply condensed the complications, to be found in Saccardo's Sylloge Fungorum and similar publications, regarding *Sphæria Cucurbitacearum* Fries and like named species found or described by others. The original specimens not being accessible, it becomes necessary to use only the published references of the names involved and therefore only suggestive conclusions may be given. Thanks are here expressed to Dr. E. J. Durand for suggestions regarding the reference "No. 1699 in Schw. Syn. N. Am. Fungi," to Prof. G. F. Atkinson for lending a specimen of Roumeguere's, labeled *Læstadia Cucurbitacearum* (Schw.) Sac., for examination, and also to the Director of the Royal Botanic Gardens, for a statement regarding specimens in the Kew Herbarium.

Sphæria Cucurbitacearum Fries published 1882, in Systema Mycologicum, II, p. 502, seems to be the original species; later de Schweinitz found what he took to be the same fungus and published it under that name as No. 1699 in his Synopsis of N. Am. Fungi (1831), referring it to Fries, though he fails to give the correct reference in Systema Mycologicum.

In an article,[37] appearing March 1883, "On Sphærella and its Allies," Dr. M. C. Cooke describes, among others, "*Sphærella* (*Læstadia*) *Cucurbitacearum* (Schwein. No. 1699); *Sphæria cucurbitacearum* Fr. Sys. Myc. II. 502." The article purports to contain additions and corrections to Volume I of

[37] *Journ. Bot.* **21:71, also copied in** *Hedw.* **22: 137.**

Saccardo's Sylloge Fungorum. This species is an addition; it seems to be an enlargement of Fries's description, with the addition of ascus and spore characters. In a note he says: "The sporidia are not mature, but the endochrome is divided, and there is every probability that they are uniseptate when mature; in fact, in some instances they appear to be so now; but this cannot be affirmed positively, although a figure beside the specimens in Herb. Berk. represent the sporidia as uniseptate."

It seems probable that the specimens used for this description come from or were collected by de Schweinitz and that they had asci and spores which Cooke describes. No doubt this is the point of departure or origin of the ascosporic species from Fries's Phoma-like fungus. Cooke evidently supposed his to be the same as that of Fries, though, of course, the latter makes no mention of asci and spores. However, it is possible that one is an imperfect form of the other; such an assumption may not be made till they have been definitely connected either from fresh material or from authentic specimens in herbaria. The former method seems possible though the latter is unlikely because most of those old type specimens seem unreliable. Ellis[38] gives a note on this species saying: "The specimen in Herb. Schw. is without fruit; immature or sterile." The Director of the Royal Gardens, Kew, writes "that *Sphærella Cucurbitacearum* Schwein. No. 1699 has not been found in the Kew Herbarium. A copy of the label of the only Schweinitz specimen of this species is given below. The specimen was originally in Berkley's Herbarium and there is a drawing at the side showing the aseptate spores 'S (*subtectæ*) *Cucurbitacearum* F. 452 Herb. Schwein.!'" A specimen of *Læstadia Cucurbitacearum* (Schw.) Sacc. by Roumegeure was examined and found not only sterile, but without even an indication of fruiting bodies.

Thus two seemingly distinct things are called *Sphæria Cucurbitacearum,* in later publications, without clearly intimating that such complications exist. Saccardo, on page XXXIII of

[38] North American Pyrenomycètes 264, Newfield, N. J.

the addenda to Vol. I., in his Sylloge Fungorum Vol. II (June 1883), gives Cooke's description in full under the name "*Læstadia Cucurbitacearum* (Schw.) Sacc.; *Sphæria Cucurbitacearum* Schw. in Fr. Syst. Myc. II., 502;" and, in Sylloge Fungorum Vol. IX (1891), page 580, the species is repeated as "*Læstadia Cucurbitacearum* (Schw.) Sacc.; *Sphærella Cucucurbitacearum* Schw., in Fr. Syst. Myc., II, 502," with no changes except in the synonym. Ellis, in Ellis and Everhart's N. Am. Pyr., page 264, practically translates Cooke's description except "Gregaria," but names it *Læstadia Cucurbitacearum* (Schw.) and gives *Sphæria Cucurbitacearum* Schw., *Sphærella Cucurbitacearum* Cke., and *Læstadia Cucurbitacearum* Sacc., as synonyms. Of course, it is possible that both Ellis and Saccardo gave their descriptions partially from herbarium material though that supposition may be incorrect as regards Ellis, judging from his note quoted on the opposite page.

On the other hand, in Sylloge Fungorum Vol. III, page 148, Saccardo gives an exact transcription of *Sphæria Cucurbitacearum* Fries (Syst. Myc., II, p. 502), with the addition of spore length, under *Phoma Cucurbitacearum* (Fr.) Sacc. Allescher expresses the same view in Rabenhorst's Kryptogamen —Flora Vol. I, part 6, page 284.

Now, from this brief view of the complications it seems probable that *Læstadia Cucurbitacearum* (Schw.) Sacc. and *Læstadia Cucurbitacearum* (Schw.) Ellis and Ev.(?), are *Sphærella* (*Læstadia*) *Cucurbitacearum* (Schwein. No. 1699) of Cooke, and that the confusion has arisen because neither Saccardo nor Ellis properly credited Cooke with the description he gave.

CROWN-ROT, ARSENICAL POISONING AND WINTER-INJURY*

J. G. GROSSENBACHER.

SUMMARY.

Crown-rot has been attributed to parasitic organisms, to arsenical poisoning and also to low temperatures. From the available literature reviewed in this bulletin and from recent observations (though there are many contradictions) there seems little doubt about its being due to low temperatures, primarily. But the relation of the main secondary factors, such as the type of soil, soil moisture, stock-scion relations, and wood-maturity, to each other and to the primary cause, need investigation; and as a consequence proper preventive measures, based upon general principles, cannot be formulated, but long expensive tests must be made to determine these matters.

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INTRODUCTION.

The name.— As stated by von Schrenk, in a short note on a fungus root-rot of apple trees, the term root-rot is too broad and probably includes several distinct diseases, some of which may be caused by parasitic organisms, others by adverse environment and some probably by both. Only a detailed study of the factors concerned in causing this group of troubles will permit a diagnostic arrangement of the separate diseases. The term Crown-rot or Collar-rot is possibly rather indefinite too, for it also includes a rotting of the upper roots and sometimes partial decortication of the trunks. Though this may be only a group name, it is used here (till some more accurate term can be found in the action of the primary cause) to designate fruit-tree injuries which usually begin at the collar, near the ground line and frequently at the uppermost roots, and extend irregularly both up and down, browning and killing bark and wood. (See plates XIII–XVI.)

The causes.— From a brief review of available literature of root-rots, crown-rots and other winter-injuries, as well as my recent observations, it seems that this disease is perhaps primarily due to adverse meteorologic and soil conditions, though another factor has been advanced as the primary cause of a disease of this type. It seems improbable that it may be caused by parasitic organisms, yet they are possibly factors in the later stages of the malady; after the normal functions of the trees have been sufficiently disturbed and some of their tissues killed. Opinions expressed in print seem mostly to agree as to the principal causes, but differ somewhat regarding the details of their operation. The relations of the significant factors are variously stated and possibly some of the important ones are still overlooked.

The problem.— Injuries of underground parts are not as easily studied as diseases of aerial structures, and then too, several only partially known factors may be involved in crown-rot. How is the stock, upon which the variety is grafted,

related to this disease and what are the anatomic and physiologic relations of stock and scion to each other: are they compatible? Also, what relation to the destruction of the cortex and the final dying of the wood to the center of the tree, have the fungi often found present on the roots, crowns, trunks and branches of affected trees? May low temperature induce injurious enzyme-action?

Preventive measures.— The prophylactic measures advised in the main agree, but in some respects they are diametrically opposed. The disagreements are not to be wondered at, since but little work has been done in an endeavor to ascertain the causes under definitely controlled conditions and but little more upon preventive measures. The best methods of orchard management and the stock-scion relation required for particular regions to reduce frost-injuries to a minimum, need yet to be determined, though some progress has been made in that direction.

REVIEW OF LITERATURE ON FROST-INJURY TO FRUIT TREES.

FROST-INJURY MOSTLY TO CROWN AND ROOTS.

The earliest available reference on this type of frost-injury, in this country, is by T. J. Burrill.[1] The most important ideas in this article bearing on the question may be very briefly stated. If late growth occurs, as may be caused by a moist, warm autumn, following a drought, a severe winter will injure the trees mechanically by freezing the relatively large quantities of water in the cambial region. It is said that ice formation in the cambial region, "together with the consequent shrinking of the tissues, * * * pushes off the bark." It seems that the crown injury observed by Burrill occurred most often on the sunny side of trees. The injury was first noticed on account of the early yellowing of leaves in autumn.

It is thought that cultivation and good drainage to secure a

[1] Climatal destruction of orchard trees. Thirteenth Ann. Rpt. Univ. Ill., pp. 283–93. 1886.

deep root-system, and mulching are good preventives. Ben Davis grafted on a hardy variety is said always to have remained healthy "while root-grafted trees perished."

A. D. Selby[2] discusses a severe case of winter-injury of an 8 or 10-year-old orchard of Baldwins, and with less injury to Grimes. A separation of bark occurred at the crown of the trees, but mostly on the south or southwest sides. Burrill's explanations and recommendations are given as preventives, with the additional advice of avoiding late cultivation. In Bulletin 121 of the same station he gives further observations stating that Grimes, King and some other varieties were severely affected. The injuries seemed to occur on any or all sides of trees, but mostly on the south and southwest. It is implied that fungi may be the cause.

Stewart, Rolfs and Hall[3] record a case of King disease or Crown-rot, and attribute it to winter-injury. A row of Baldwins near the center of an orchard was much affected. Various sized areas of bare wood occurred at the base of trunks. The bark was said to have loosened two years previous and normal callus ridges bounded the wounds. In a few cases only narrow strips of living bark bridged the girdled crown.

What, no doubt, is the same disease, is reported in the same bulletin, on apricots. In one orchard where gaps, which had been caused by a collar-rot, had been filled with trees on various stocks without success, the injury seemed to begin at the union (just under the ground); above which a dead girdle of cortex several inches wide was produced, and often ended in a sharp line at the living stock. It is stated that the disease was possibly "brought about by the combined effect of uncongenial soil, uncongenial climate and imperfect union." Two other orchards were found to have affected apricot trees with dead areas of bark from the ground upward, much like a case

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[2] Some diseases of orchard and garden fruits. Ohio Agrl. Expt. Sta. Bul. 79, pp. 135–6. 1897. Bul. 121. A condensed handbook of the diseases of cultivated plants in Ohio, 1900.

[3] A fruit-disease survey of Western New York in 1900. N. Y. Agrl. Expt. Stat. Bul. 191, pp. 302–3. 1900.

described in an earlier bulletin[4] of the same station. A Cytospora was found on the dead bark and considered a parasite.

To show that the earliest observations on winter-killing of apple-tree roots are ancient, J. Craig[5] quotes instances from horticultural society reports of Minnesota, Iowa and Wisconsin dating back to the early seventies. In these reports it is held that bare ground during severe winters permits root-injury and that mulching is a preventive. Craig observed that the basal portions of the upper roots, even of old trees, were severely injured during the winter of 1898–9. The region of greatest injury was found on the stock (near the ground line) from the base of the scion downward even to the depth of 10 to 12 inches; below this injured girdle the roots were unaffected. Slight injury is said to have been shown by the discolored cambium and severer effect by the disorganization of the inner bark. Seedling roots were more often injured than scion roots on root-grafted trees. In fact it seemed that the trees escaping destruction were generally found to be dependent on a scion root system, though surface protection is thought to be the more important factor. Trees 5–15 years old were least injured and orchards on south slopes or on loam soils were less affected than those on north slopes or sandy soil. It is stated that fruit growers are agreed that severe, long, cold periods and unprotected ground are the primary causes of root injury, but that they differ as to the relation the amount of soil-moisture has to this injury. Some hold that a dry soil is conducive to winter-killing of roots and others that a wet autumn preceded by a drought is the decisive factor when followed by a severe winter. According to the latter theory, which is thought plausible, freezing of the excessive water in the roots causes mechanical injury to the tissues.

Ben Davis is considered less hardy than Pointed Pipka, but varietal hardiness is said to be unable to prevent injury when the ground is bare and the temperature very low. The hardi-

[4] N. Y. Agrl. Expt. Sta. Bul. 167, p. 286. 1899.
[5] Observations and suggestions on the root-killing of fruit trees. Iowa Agrl. Expt. Sta. Bul. 44. 1900.

ness of the scion seemed not always indicative of a hardy stock. The least affected varieties arranged according to their decreasing hardiness are said to be Siberian crabs, native crabs, Hibernal types of Russian apples, varieties of western origin, such as Northwestern, Patten Greening and varieties like Wealthy, Duchess and Tetofsky.

In localities of severest cold and least snow covering, the trees in neglected, weedy nurseries were least injured, though varietal hardiness, deep planting and the extent of the scion root-system seemed also decisive factors. Banking and heading back are advised for injured nursery stock to induce the development of scion roots. The commercial apple stocks are thought to be unsatisfactory; a hardy seedling stock should be secured.

For orchards already planted, deep plowing in the spring followed by shallow cultivation till mid-summer, is advised, thus inducing early growth and the consequent early ripening of the wood as well as to conserve soil moisture. A good cover-crop, such as clover or vetch, is thought highly important to prevent frost-injury of the roots.—To prevent injury to trees to be planted, it is suggested to plant unusually deep, especially on well drained soils, not filling the holes completely but allowing subsequent cultivation to fill them. The final conclusions are that a lack of a snow-covering and low temperature combined are the chief causes of root-rot in nursery and orchard trees and that most injury occurred on clean-cultivated dry knolls with northern exposure. Cover-crops and deep planting are thought of paramount importance.

Aven Nelson[6] suggests that since winter-killing is more common in Wyoming than in other States having equally low temperature, desiccation is the principal cause. High, dry winds and low barometer are given as the causes of desiccation. Late irrigation and mulching with straw, leaves or manure are advised.

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[6] The winter-killing of trees and shrubs. Wyo. Agrl. Expt. Sta. Bul. 15. 1893.

Some rather suggestive results along that line were obtained by R. A. Emerson[7] from an experiment designed to indicate the relation of different percentages of soil moisture and mulching to winter-injury of roots. One-year-old apple and two-year-old cherry seedlings were planted in boxes of loam soil of various degrees of moisture. Some of the boxes were put out on open ground and one into a cool, dry cave. In the open some boxes were mulched and others left exposed. The experiment was begun in December and ended in February.

None of the cherry roots seemed injured severely enough to prevent further growth, while many of the apple roots were much damaged. The dead, brown cortical regions from the surface of the ground down one to seven inches, observed on a number of these trees, have a suggestive resemblance to Crown-rot. It seems that similar injuries were found on other young trees which were not in the experiment. The tops of these root-injured trees were generally unaffected. The apple seedlings in unmulched soil with 10.4 per ct. soil moisture were injured decidedly more than those in boxes with 25.6 per ct. of moisture content. Straw mulch seemed to lessen liability to frost-injury due to low moisture content of the soil. "Just why severe freezing should injure roots worse in rather dry than in moist soil is not shown by the test reported above. On further investigation it may be found that roots are simply unable to withstand severe freezing or to recover from it unless surrounded by an abundance of moisture. Be this as it may, it is quite probable that one cause of the great injury in rather dry soil is alternate freezing and thawing." Emerson thinks that piece-root grafting of hardy varieties (making own-rooted trees) is advisable and also that budded trees should be planted deep. Cultivation and cover-crops are recommended.

More recently, he published[8] some observations on the relation of a tree's wood-maturity and its resistance to cold. It

[7] Experiments in orchard culture. Nebr. Agrl. Expt. Sta. Bul. 79, pp. 26–32. 1903.
[8] Nineteenth Ann. Rpt. Nebr. Agrl. Expt. Stat., pp. 101–10. 1906.

is concluded that the relative maturity of tissues, rather than constiutional hardiness, determines the resistance to low temperature. But it is admitted that with some plants immunity is a constitutional matter. It is therefore important that sorts be used which mature early. Planting on high ground and using a cover crop may induce earliness.

W. Paddock[9] has also published some observations on a case of apple tree root-rot. It is thought that the weakening of trees by such agencies as excessive irrigation, winter freezing and woolly aphis enable root-rotting fungi to injure and decay roots. Cultivation, cover crops and less irrigation are recommended.

Some interesting observations on winter-injury are recorded by G. P. Clinton[10] in the Connecticut Experiment Station Reports. In the Report of 1903 good examples of Crown-rot as well as other types of winter-injury are described.— The mild fall of 1902 was followed by zero (F.) weather on December 9. In nurseries or young orchards receiving late cultivation, the injury was mostly to the wood, the cortex remaining unharmed. Several injured, transplanted trees died during the following spring or summer, but when left in the nursery, cut back and banked, they were often saved.

Orchard trees four to eight years old generally developed dead areas in the bark, usually at the base of the tree and most commonly on the north side. In some cases the crown was completely girdled. Even much injured trees leaved out normally in the spring, but in July the leaves began to drop. Though a fungus was found in the canker-like spots, it was considered secondary.

In the next report, the injuries caused by the severe winter of 1903–04 are described. The affected trees became evident again during the summer in young orchards and nurseries by severe injury to the wood down to the snow line or ground.

[9] Colo. Agrl. Expt. Sta. Bul. 69, pp. 4–6. 1902.

[10] Conn. Agrl. Expt. Sta. Ann. Rpts. 1903, pp. 303–4; 1904, pp. 312–13; 1906, pp. 310–11; 1908, pp. 879–90.

Cutting back and cultivation seemed to help them. As previously reported, the injury to bearing orchards was confined to the bark, mostly at the crown, younger trees sometimes being girdled and shedding many leaves during the summer. It is advised to remove the dead bark and paint over to prevent rot. It is thought that high, exposed hillsides are preferable to lowlands for orchards, more injury occurring on the latter. Late cultivation and excessive fertilization should be avoided.

In the Report of 1906 he gives observations on some typical apple-tree cankers which were studied in longitudinal and cross sections. "The cankered areas occurred on the sides most injured, and apparently the canker fungus largely got a start here through the smaller twigs that had been entirely winter killed."

A thoughtful discussion of the "chestnut bark disease" is printed in his Report for 1908, in which a number of weighty reasons are given to show that *Diaporthe* (*Valsonectria*) *parasitica* is not the primary cause of the chestnut tree disease of part of the Atlantic slope, but that winter-injury is responsible.

Another brief but significant note on Crown-rot was published by O. B. Whipple,[11] in which two types of root rot are reported, one showing no preference for varieties and rotting only underground parts, the other affecting only the Ben Davis and Gano, but injuring both trunk and roots. The second type is said to be very destructive; the bark turns brown and the yellowing leaves drop early. The disease is thought to be infectious because Ben Davis trees, which were situated so as to receive drainage water from affected ones, were also found injured. However, the suggestion is made that "Ben Davis and Gano are very tender as regards the application or arsenical sprays * * * arsenic collecting about the crown of the tree and killing the bark."

W. T. Macoun[12] gives an extended discussion of frost injury, stating also that many trees were root-killed and crotch-injured

[11] Colo. Agrl. Expt. Sta. Bul. 118. 1907.
[12] Canad. Exptl. Farms Ann. Rept. 1908, pp. 110–16.

during the winter of 1895–96 on the farm at Ottawa. Very little snow fell during the winter and no cover crop was used. Macoun thinks that sod may protect roots when there is enough moisture in the soil, but since sod soil is often too dry, it is thought best to cultivate to conserve the moisture and then use a mulch or cover crop.— No winter-killing of roots has been observed since 1896, which is thought to be primarily due to the use of Crab, Martha and Transcendent seedlings as stocks, though it is conceded that the use of cover crops may also be an important factor.

FROST-INJURY MOSTLY TO AERIAL PARTS.

Winter-injury to aerial parts of fruit trees frequently occurs when the roots and crown are but little affected. However, since the effect on the wood tissue is very similar to that often accompanying Crown-rot, it may not be amiss to include a few cases in this review

L. R. Taft[13] published a discussion of "Frozen Trees and Their Treatment," in which it is said that many trees were injured or killed in Michigan during the very severe winter of 1898–9. The injury was generally manifest by the browning of the wood and bark, though sometimes only the former. When only the wood was discolored it is thought that the trees might produce several crops, if properly treated, but when the bark has become loosened to a considerable extent, their death seems likely to follow. In case of peach trees under four years, which had been severely injured above the snow line, it is advised to cut them back and train sprouts from the stubs, but when only the branches are affected, they should be headed back. When the trunks and branches of bearing trees are much injured, they should also be headed back to "four or five arms" so that the sap would not need to pass so far through injured wood. The less severe cases of bark loosening may also be overcome by cutting away the loose bark and covering with grafting wax. Cultivation, fer-

[13] Mich. Agrl. Expt. Sta. Spl. Bul. 11. 1899.

tilization, pruning and spraying are advised as rejuvenating measures.

"Winter killing of peach trees" is also discussed at some length by Green and Ballou.[14] Various factors are enumerated which were said to reduce the vitality of trees so as to make them more susceptible to winter injury. An instance is cited where an orchardist banked some of his trees with barnyard manure and soil in the autumn preceding a severe winter. The unprotected trees in the same orchard "died almost to a tree" while the banked ones came through the winter uninjured. The orchard was on very stony and dry land.

A case of "Fruit trees frozen in 1904" is recorded by M. B. Waite,[15] in a Bureau of Plant Industry bulletin. Peach orchards in low, flat regions were much injured. Trees most severely affected had the bark of their trunks completely killed and often separated from the much-browned wood. However, about half the trees in the affected orchards were less injured. In these cases the snow-line region of trunks had browned wood and sometimes loosened bark with living cambium and dead young wood cells just within it. The fruit buds were found more resistant than the young wood and the cambium and leaf buds more than any other part of the trees. Trees one to three years old were said to be less affected than bearing ones, though nursery trees were found killed to the snow line. It is advised that peach trees with the bark injured only near the snow line, even when partially loosened, be moderately pruned, well cultivated and fertilized to save them.

Pear orchards are also severely affected, but a pear tree's power of recovery is said to be slight compared to the peach; though the bark may seem but little injured, when the wood is browned the trees are thought to be unable to recover. It is suggested to cut them off at the snow line and grow sprouts from the stumps.

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[14] Ohio Agrl. Expt. Sta. Bul. 157.
[15] U. S. Dept. Agr., B. P. I. Bul. 51, pp. 15–19.

Later in the same year H. J. Eustace[16] described some cases of "Winter injury to fruit trees." The injury caused by the winter of 1903–04 was said to be due to the early summer drought and heavy, late autumn rains of 1903 combined with fungus and insect injuries. The cambium layer is considered the part of trees first injured or killed, and dessication through freezing the primary cause. Though it was not seen externally that peach trees were injured, both bark and wood of trunks were browned, especially just above the snow line. It is said that some peach and pear trees, having much discolored bark and wood from the snow line up into the branches, made a very good growth during the summer and produced fruit the second season. The older peach trees were much more severely injured than the young ones and made a less rapid recovery. Trees in low places were often entirely ruined while those on some heights bore fruit. But varieties were found to differ in their resistance to cold. Four varieties in one orchard of 730 trees had the following relative hardiness: Stevens Rareripe produced a fair crop; Bray, some fruit; Elberta, a few fruits; and Reeves Favorite, no fruit. The trees in a one-year-old orchard of Baldwins and Rhode Island Greenings were killed back to within three feet of the ground, while Ben Davis seemed uninjured.—A Kieffer pear orchard is cited where "the bark and wood were discolored black all through" in March, but which produced a fair crop. Some much-injured, old pear and peach trees were severely cut back in April: practically all died, while those left unpruned came through better and those moderately pruned best. But cutting back seemed to help young trees.

Selby[17] gives extensive observations on a case of winter injury "to orchard trees and shrubby" in which mostly the aerial parts seemed to have been affected. The rather cool, yet weather during the early-summer of 1906, followed by the

[16] N. Y. Agrl. Expt. Sta. Bul. 269.

[17] Fall and early winter injuries to orchard trees and shrubbery by freezing. Ohio Agrl. Expt. Sta. Bul. 192. 1908.

unusually warm, moist late-summer and fall, resulted in much and very late growth of apple trees in both sod and cultivated orchards. No light frosts occurred to check growth and ripen the wood till the cold wave of October 10–12, with a minimum of 18° F., killed many trees to the ground or snow line and produced dead, brown areas on the bark of others, especially in orchards where the trees had been set less than five years. Though some injured or dead trees could be located in February, many severely affected ones showed no evidence of injury till midsummer, when their foilage became discolored, followed in many cases by death in late summer.

On various parts of the most exposed sides of trunks, sunken, brown, canker-like areas appeared. But the injury could generally be noticed first by the presence of a brown inner-bark. At times, when the surrounding bark had grown sufficiently in thickness, a more or less definite crevice appeared, separating the living and dead bark.

In several orchards cited 80-100 per ct. of the young Baldwin trees were either killed or severely injured and Rome Beauty fared but little better, while Ben Davis, Gano, Northern Spy, Jonathan and perhaps Grimes proved more resistant. It is suggested that the hardiness of a variety depends upon its relative earliness of growth and ripening of its wood, and that susceptible varieties which are very desirable, be top-grafted on resistant sorts.

The indirect effects of the severe winter-injuries of 1906–07, it is thought, would be noticeable for several years, since dead areas in the bark hinder "sap flow" and afford entrance for wound fungi which may rot the trunk or roots.

As may be expected, winter-injury to fruit trees has also been recorded in Maine, though for obvious reasons mostly to trunks and branches. W. J. Morse[18] says that in an orchard survey, after the very severe winter of 1906–07, it is shown that 11 per ct. of the trees in 950 orchards were either killed or injured. Baldwin and Ben Davis seemed most susceptible;

[18] Maine Agrl. Expt. Sta. Bul. 164, pp. 12–21. 1907.

however, Northern Spy, Greening and others were also affected. Though many injured trees had dead areas of bark on their trunks and large branches, in the spring of 1907, the most striking effect in an orchard of 1200–1500 twelve-year-old, Ben Davis and Stark apple trees, was shown at the crotches. It seems that about 75 per ct. of them were affected more or less. The dead bark of the injured crotches seemed recently killed and due neither to bacteria nor fungi. It appears that in most cases in which trees were not killed, crotch-injury was very conspicuous. It is thought that the accumulated ice in the crotches is the cause of the injury or canker.

REVIEW OF LITERATURE ON FUNGUS INJURY TO FRUIT TREES.

Several fungi of the hymenomycetous group are found more or less constantly about injnred or decaying roots and crowns of forest and other trees many of which are still living. Possibly a few of these are true parasites, though most of them probably only disintegrate non-living tissues of injured or dead trees. For some reason or other strict inoculation tests were generally deemed unnecessary to determine the pathogeneity of these fungi, the nearly constant presence of a fungus on injured or dead trees of one or more species having often been accepted as proof sufficient. Yet it may mean nothing more than that certain types of non-living tissues are suitable substrata for certain fungi.

Other fungi are commonly found on areas of dead bark of cankers of the trunks and branches of trees. It is often difficult to determine what killed the bark, especially when examined in mid-summer or later.

FUNGI ON THE ROOTS.

An extensive article on root-rots of trees was published in 1896 by F. Cavara.[19] It is there held that many supposed

[19] Contribuzioni allo studio del marciume delle radici e del deperimento delle piante legnose in genere. *Staz. Sper. Agrar. Ital.*, **29**: 788–814. 1896; reviewed in *Ztschr. Pflanzenkrank.*, **7**: 360–1. 1897.

saprophytic fungi cause the death of trees. The sporophores of the following species were found on the crowns and roots of forest trees which were evidently diseased or injured more or less: *Tremellodon gelatinosum, Polyporus versicolar, Tricholoma saponaceum, Micena epipterygia, Pholiota aurivella* and *Lycoperdon gemmatum.* R. Aderhold[20] also described "Eine Wurzelkrankheit junger Obstbaumchen." About 5 per ct. of the apple and cherry trees died in certain nurseries during mid-summer. The browning of the cambial region was the first indication of injury. The mycelia of two fungi were found present on many injured roots, and that of one, on all affected ones. The fungus always found present Aderhold thought may possibly be *Fusarium rhizogenum.* Inoculation experiments were ttried with both fungi on apple and cherry roots but all were negative except one wound inoculation with Fusarium. In this case two small fibrous rootlets near the base of which the inocluation had been made, died and developed the Fusarium mycelium, when placed in a moist chamber, though the inoculated root seemed to remain healthy. However, Fusarium was held to have caused the death of the nursery-tree roots.

A very lengthy description of a root fungus is given by E. M. Wilcox.[21] In the summary it is stated that "The root-rot disease herein described is found in many of the orchards of the Southwest and is very common throughout many parts of Oklahoma."

A rhizomorphic strand was found entering the cortex of a living Ben Davis tree through one of its dead roots. Cases are also said to have been seen where the fungus entered the crown first and then spread to the roots. But in many cases no mycelium was found "more than five or six inches above the crown."

"A root-rot of apple trees caused by *Thelephora galactina* Fr." is discussed briefly by H. von Schrenk.[22] Three to six-

[20] *Centbl. Bakt. u. Par.,* II, 6: 620–5. 1900.
[21] A rhizomorphic root-rot of fruit trees. Okla. Agrl. Expt. Sta. Bul. 49. 1904.
[22] *Bot. Gaz.,* 34: 65. 1902.

year-old trees are said to die in various states of the Middle West as a result of the parasitism of this fungus, especially in orchards on recently cleared land. Trees with injured root systems become evident by their over-production of fruit.

The fungus was transferred from oak roots to apple roots and is said to have proved deadly within the year. Further studies were promised but seem not to have appeared. At any rate, in Bulletin 149 of the Bureau of Plant Industry on "Diseases of deciduous forest trees," by von Schrenk and Spaulding, only brief mention is made of this fungus as causing the death of oaks and getting on fruit trees in newly cleared land.

FUNGI ON TRUNKS AND BRANCHES.

Perhaps the best-known example of the fungi commonly found on dead bark or cankers of trunks and branches of apple trees in this region was described by W. Paddock.[23] This Sphæropsis canker was found doing very much damage, especially on Esopus Spitzenburg, Twenty Ounce, Baldwin, Wagener, Greening and King, while Tolman Sweet was found resistant.

The affected trees are characterized by rough, enlarged regions on the larger branches and areas of dead bark on the trunks. Sphæropsis pycnidia appeared on most cankers, while on others the fungus is said to have died. Sometimes a branch having wilting or dying leaves is found to have a girdle of dead bark which is said to "cut off the flow of sap." However, it was shown by Paddock that Sphæropsis mycelium penetrates the wood but seldom.

Sphæropsis is said to infect trees in spring, becoming evident as areas of discolored bark which seem to spread till mid-summer and then produce pycnidia. Infection is supposed to occur at wounds and injuries of various kinds on trunks and branches. It was shown by numerous experiments that the fungus could produce cankers when introduced under living bark, but that it seems unable to do so when placed just

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[23] The New York apple-tree canker. N. Y. Agrl. Expt. Sta. Buls. 163 (1899) and 185 (1900).

under the outer bark of a living tree. It appears, however, that in all but one instance of the 1898 inoculations Sphæropsis failed to live over winter, since only one of the cankers increased the following summer.

The devastation by Sphæropsis is said to have been considerable in the nineties. In one case the major part of a large, thrifty, well-tilled orchard was destroyed, while a short distance away an orchard on poor soil and kept in sod was but slightly affected; though inoculation experiments indicated that vigorously growing nursery trees were less affected than unthrifty ones.

It is advised to scrape the trunks and branches of trees and wash them with a soap, lime and wood-ash mixture. Cankers and cankered limbs should be cut out and all wounds covered with paint or grafting wax.

A. B. Cordley,[24] of Oregon, also describes an apple-tree anthracnose.

This Glœosporium is said to form cankers on the bark of branches mostly two to three inches in diameter, though larger limbs and the trunks are also affected. The first indications of the canker appear generally after the autumn rains as small, irregular brown areas on the bark, spreading slowly during winter and rapidly in spring, but ceasing in May. The pycnidia are produced from June to September on the brown, depressed areas, which are often limited by irregular fissures. The dead bark drops off in a few months, "leaving a wound which requires several years to heal." Occasionally a canker girdles and kills a branch.

Thirty-six mycelial inocluations were made in the bark of short sections of small, live apple-tree branches, which were placed in the sand of a moist chamber. The characteristic dead areas appeared in three weeks.

Another case of apple-tree canker was described by H. Hasselbring,[25] and ascribed to a species of Nummularia. The

[24] Apple-tree anthracnose. Oreg. Sta. Bul. 60 (1900); and a more detailed account. "Some observations on apple-tree anthrocnose," *Bot. Gaz.*, **30**: 48–58. 1900.

wounds usually occurred on large limbs near the trunk, from which they extended up and down. The dying bark of the canker spots was first of a dirty brown color, later becoming rough, charred and punctured by "grayish ochre" colored stromata of the fungus. It is thought that the mycelium advances more rapidly in the wood than in the bark because limbs "examined at points several feet away from the cankered spot" had "brown and discolored" heart-wood. A branch dies by the time or before it is girdled. It is considered a wound parasite, which gains entrance through dead stubs, pruning wounds, etc.

H. H. Whetzel[26] attributes a common form of apple-tree canker to the fire-blight Bacillus. Blight canker is said to have occurred very commonly in the upper Hudson River Valley and other parts of New York State, on trees 8–15 years old. About 95 per ct. of such trees were more or less affected on their limbs and trunks by this canker, and many of them were dead or dying. Crotch-cankers were found on numerous young and old trees, but it was thought that young trees were more often killed than older ones.

The beginnings of these cankers were more readily noticed on young, smooth-barked trees, as discolored, sunken areas with slightly raised or blistered margins, and sometimes exuding a sticky fluid largely composed of bacteria, but fungi were found present only some time after the death of the bark. The dead bark soon turned brown and later dropped off. Wet, cloudy weather is said to favor the spread or extension of cankered regions and sunlight to check them. Most cankers were limited to but one season's growth, though some were said to be perennial in their progress.

It is suggested that the large cankers at the bases of young trees and the disease on the crowns of King may also be due to the canker Bacillus. Collar-rot and crotch-cankers were thought to be the most destructive types of injury.

[25] Ill. Agrl. Expt. Sta. Bul. 70. 1902.

[26] The blight canker of apple trees. Cornell Univ. Agrl. Expt. Sta. Bul. 236. 1906.

It was shown by inoculating Bacillus into the bark of apple trees that the typical cankers resulted, and also that twig blight could be produced by introducing the organism into the bark of pear and apple twigs. It is suggested that Bacillus cankers may be expected in any region where fire-blight of pear and apple is prevalent.

Wolf River and Tolman Sweet appear to be resistant, while Baldwin and Ben Davis are very susceptible.

Blighted water sprouts and short spurs, which had been infected with Bacillus through insect and other injuries, were said to have been the beginning points of many cankers of trunks and branches. Pruning and other wounds are considered important places of infection. It is advised that cankers be cut out, disinfected with a corrosive sublimate or a copper sulphate solution and then painted over with some heavy lead paint; also that all dead twigs and water sprouts be pruned out, disinfecting and painting the wounds.

REVIEW OF LITERATURE ON ARSENIC-INJURY TO FRUIT TREES.

A rather interesting addition to the Crown-rot discussion is contributed by W. P. Headden [27] under the caption, "Arsenical poisoning of fruit trees." Headden holds that the root and trunk injuries described by Whipple [28] on Ben Davis and Gano are typical cases of arsenical poisoning (a possibility suggested by Whipple), and that Spitzenburg, Early Harvest, Wolf River, Lawver, Blacktwig, Baldwin, Jonathan, Grimes and Pewaukee are also affected.

It is stated in the bulletin that the excessive application of arsenical sprays, as practiced in some sections of Colorado to combat the codling moth, and the consequent accumulation of arsenic under the trees are sufficient to injure or kill them. It was estimated that 0.9 pound of arsenate of lead, or 0.225

[27] Colo. Agrl. Expt. Sta. Bul. 131. 1908.
[28] Colo. Agrl. Expt. Sta. Bul. 118. 1907.

pound of arsenic acid is sprayed on each tree in one season. Soil near the bases of these trees taken from depths of 4-12 inches yielded 25.5-61.3 parts of arsenic acid per million parts of soil. Most Colorado soils are said to contain from 0.2 to 1 per ct. of alkalis ("sodic carbonate, sodic sulphate and sodic chloride"), and Headden thinks that the accumulated insoluble arsenic salts are converted to soluble compounds by the alkalis in sufficient quantities to cause the death of the trees.

"The crown of the tree is found to be girdled, the bark on portions of the trunk dead and sunken and most of the roots dead, their bark destroyed and the woody tissue discolored, usually a light shade of brown and sometimes exteriorly blackened." "The limbs and branches of trees affected in this way usually, but not invariably, present a case of 'black heart.'"

Samples of wood were taken from 11 apple and 3 pear trees and all gave the arsenic test. From 1.25 to 12.77 parts of arsenic per million of wood tissue were found in the few cases in which quantitative determinations were made. To test the toxic properties of arsenic .05 to .5 gram portions of "sodic arsenite" were added to the soil of herbaceous greenhouse plants "in two and a quarter to three-inch pots," resulting in the death of all treated plants. A case is cited where some arsenite of soda was said to have been emptied into an irrigating ditch twelve feet from an apple tree; two days afterward one of its large ditch-ward branches appeared diseased. A dead, decorticated root was found to extend to the ditch while some other roots seemed normal. A strip of bark on the trunk, between the affected root and branch, was found to be brown and dead. Thus it seemed that the arsenite of soda was absorbed by the tree, causing the death of both root, branch and intervening bark. The typical "black heart" of the affected trunk and branch was present. The root contained 34.5 parts of arsenic acid per million parts of tissue.

The solubility of lead arsenate was tried by suspending 1 gm. in 2 l. of water and adding 2 gms. of Glauber's salt.

After three days considerable arsenic had gone into solution. A repetition of the experiment, using 1 gm. of common salt, gave similar results. Lime arsenite was also found soluble to a high degree. It seemed therefore that the presence of lime sulphate in the soil would not prevent arsenic going into solution. Though lead was found present in the injured trees lime arsenite is thought to have been the probable cause of the trouble. Both arsenic and lime were found present in exuded sap of injured trees and it is held that both had been injurious to the trees.

SOME ORCHARDS STUDIED DURING THIS AUTUMN.

Introduction.— Perhaps about half a dozen orchards were studied more or less during the present autumn to obtain some information regarding Crown-rot. Sod orchards were generally found but little affected by either this trouble or by other cankers, while all cultivated orchards visited were considerably marked by Crown-rot scars, though often but slightly by ordinary cankers. Cultivated orchards on thin, stony land seem more injured than those on deep, rich soil and are decidedly less able to recover. On deep, rich soil one often finds old apple trees with Crown-rot wounds which are surrounded by 8–14-year-old callus rolls. On thin, stony land all severely injured trees seem unable to recover, dying in a few months or years. Cankers or crown-injuries in any affected orchard seem to date back to some one or more seasons. Often 2 to 14 years appeared to elapse between the occurrence of injuries.

Mushrooms, such as Pleurotus and others, were sometimes found about affected crowns and roots, and fungi like Cytospora and Sphæropsis were common on canker-like upward extensions of Crown-rot. However, on the older, recovered trees having callus rolls around old injuries, bark fungi were absent.

Sodus orchard.—An apple orchard of twelve to fourteen-year-old trees was visited near Sodus, N. Y., Oct. 2, and found

affected with Crown-rot. One section of this orchard consisted of 120 Ben Davis, another of 60 trees, 50 of which were Ben Davis. Only the Ben Davis were affected by the Crown-rot, though in another part of the orchard a few older trees of other varieties had old, callus-margined wounds about their crowns. The orchard is on rolling and somewhat thin, gravelly soil. The Ben Davis orchard was in sod until 1905, when it was planted in corn. On account of the cold, wet spring, cultivation was continued till August. The orchard was tilled from 1905 to 1908 and then allowed to develop a red-top sod. No spraying of any kind had been done. Nineteen of the 170 Ben Davis trees were more or less visibly affected, six of which were practically killed and taken out, i. e., about 11 per ct. of the trees were injured or killed.

The affected Ben Davis trees could generally be located by their yellowish foliage and sometimes by their wilting fruits. Such trees were found to have wounds at their crowns or about the upper end of the stock. The injuries often consisted of long, narrow, dead regions with more or less decayed bark, surrounded by thin, irregular callus ridges of about two or three years' growth. Some trees had only one to three wounds around their crowns, ranging from one-half to three inches wide and from two to five inches long, while others were entirely girdled (as may be seen from plates XV and XVI). In some instances portions of bark above the crown wounds seem to have died during this summer. The small wounds were usually about the upper angles of roots. In case of completely girdled trees all lateral roots in the girdle were dead and decorticated. One tree with a broad band of decaying cortex had a large lateral root near the surface of the ground, seemingly from the scion, which was partly living. (See Plate XVI.) The roots below the girdles, about the terminal end of the stock, were usually still unaffected.

Longitudinal and cross sections of the crowns of four severely affected trees differed much in appearance. Some had

living, natural-colored wood out to the cortex, while others had dead, discolored wood to various depths toward the center of the trees. Often a wedge-shaped, dead portion of wood, including a dead root, extended toward the center of a trunk, while the other wood was living throughout. Trees showing marked evidence of Crown-rot always had one or more such root-wood sectors of dead wood extending nearly to the center (as shown in Plate XVII). From cross-sections it seems that the trees had been injured after the growing season of 1905 or 1906, though it was not certainly determined owing to indefinite growth rings. The injury seems to have occurred after the first cultivation of the orchard.

The right-half of the stump shown in longitudinal section (Plate XVII) and a piece of another stump were sent to W. P. Headden, October 14, and he says they look like his arsenical poisoning cases and analysis showed that they contained arsenic.

Coxsackie orchards.— Other cases of Crown-rot were studied in well-tilled orchards near Coxsackie, N. Y. The injury seemed also to have occurred about two or three years ago and had a similar effect upon the trees. Some two to eight-year-old Baldwins, Greenings and Ben Davis were severely affected; about 13 per ct. of the Baldwins and 10 per ct. of the others. The orchards are on rolling, gravelly land which had been thoroughly fertilized and cultivated, but the trees were never sprayed. They had been banked with soil in the falls of 1907 and 1908. A neighboring sod orchard of the same age, but getting little care, had no evidence of the trouble; the trees were smaller but looked healthy.

Geneva orchards.— One of the largest and probably the best, tilled orchard in the vicinity of Geneva, N. Y., consisting largely of Baldwin and Greening trees at least 45 years old, has over 6 per ct. of its trees affected with old Crown-rot scars. Various sized areas of bare wood, surrounded by about thirteen-year-old callus rolls, are present on the crowns, especially on the higher, thinner land, while lower parts with deeper soil seem to have fewer scarred trees. However, all the old

scars seem to have originated during the same winter. On the higher, slightly gravelly knolls a few scarred trees were found with early yellowing foliage and decaying heart-wood. But in spite of these injuries and some gaps where trees had been removed, the orchard is probably the thriftiest and most productive in this region. It has been tilled about 15 years, but before that time it was pastured. It seems probable that the Crown-rot injuries occurred during the winter following cultivation, os in the Sodus case, but the good, deep soil with plenty of moisture enabled the trees to recover.

A small and somewhat neglected sod orchard over thirty years old was found to have no gaps or replaced trees nor any visible crown or trunk injuries, though the soil and location seemed practically the same as in the neighboring orchard just described. It appears that but little spraying was done.

Experiment Station orchards.[29]—Though many of the most affected trees were taken out of the Experiment Station orchards at different times, there are still about 3 per ct. of the older ones which have old Crown-rot scars. Some of the younger ones were evidently severely injured during recent years because the killed bark at their crowns has not yet entirely decayed, though the upper roots are devoid of cortex.

The last stage of such a case is shown in a photo of a nine to eleven-year-old Ben Davis which had green bark from about one and a half feet above ground upward, though its leaves had all died and its fruits wilted. (Plates XIII and XIV.) The roots were not only decorticated, but dead throughout. The bark was still adhering to the dead, lower part of the trunk, though it was much roughened and cracked. Cytospora and Sphæropsis were present on the trunk canker. A longitudinal section about one and a half feet above the ground shows the transition from living to dead alburnum or sap-wood and bark, though the heart-wood was discolored and dead at least several feet above. This tree was probably injured during

[29] Thanks are due M. J. Dorsey of the Horticultural Department of this Station, for looking up the records of some injured trees.

the winter of 1902–03, for its record shows that it had been marked in 1903 to be taken out.

Cross-sections near the ground of a few of the older trees, taken out this autumn, may be seen from plates XVIII to XX. Several varieties are included. It is plainly evident from the blackened frost-line of some, that it was the youngest wood inside the cambium and not the cambium itself that was killed. As may be seen, wood-rotting fungi destroyed the woodcylinder inside the frost-line of some examples (plates XIX and XX), though others are unaffected (plate XVIII). Sporophores of a Pleurotus were found on the one having but three bridging regions of live alburnum and bark. In some instances frost-lines could not be seen in cross-sections four feet above the crown, while in others they were evident in sections of branches. It was difficult to determine the exact number of growth rings developed since the injury occurred, but it certainly seems a safe estimate to say that it happened from 12 to 14 years ago, and very probably the latter. The callus rolls are mostly normal, though they were evidently injured in some instances. A few of the upper roots of each of these trees were more or less rotted, yet fair crops of apples had been harvested from them in recent years.

Crown-rot, like Bacillus blight, seems most prevalent in thrifty orchards. In two of the examples described, the winter-injury seems to have followed the first cultivation of sod orchards, but there may have been other factors involved. However, there seems no doubt but that an unusually heavy succulent growth, which leads to late maturity of the young wood, is one of the *main* secondary factors concerned in the occurrence of both of these troubles.

Portions of the crown, trunk and branches of a dying, Crown-rotted, Bottle Greening tree (which has been set nine years) were sent W. P. Headden by F. C. Stewart. He reported, by letter, that arsenic is present in diminishing quantities from the crown upward. So it seems that, although

PLATE XIII.— A CROWN-ROTTED BEN DAVIS APPLE TREE.
Tree had died a few days before it was photographed. Sphæropsis and Cytospora were present on dead bark below 1 and 2.

PLATE XIV.—SECTION OF TREE SHOWN ON PLATE XIII.
Tree had been entirely killed up to 1 and 2 before its top wilted.
(1 and 2 also indicated on Plate XIII.)

Plate XV.— A Crown-rotted Ben Davis Apple Tree.
Tree completely girdled and all upper roots decorticated, but roots under center of tree still normal.

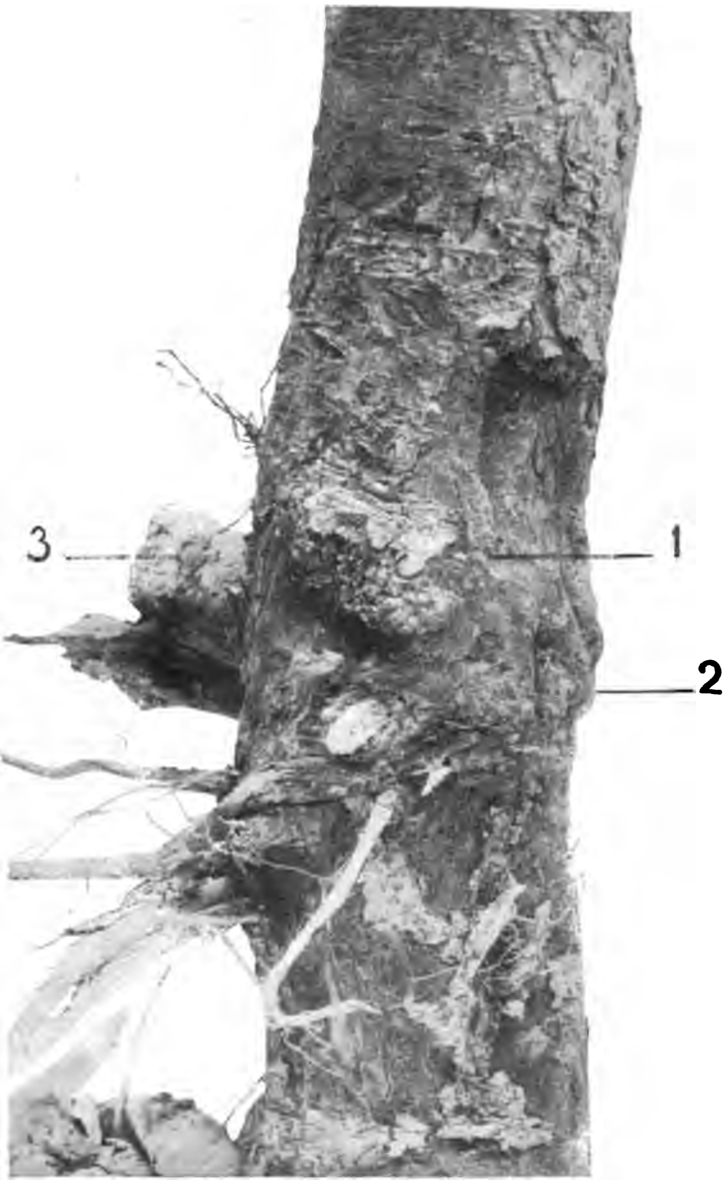

PLATE XVI.— A GIRDLED BEN DAVIS TREE FROM SAME ORCHARD AS TREE IN PLATE XV.

1, Normal but irregular callus-roll; 2, union of stock and scion (collar); 3, partially green scion-root.

PLATE XVII.— LONGITUDINAL SECTION OF TRUNK IN PLATE XVI.
1, Shows thickness of callus-roll; 2, discolored region of wood.

PLATE XVIII.— SECTION OF A KITTAGESKEE APPLE-TREE NEAR GROUND LINE.
Shows low-temperature injury that failed to develop Crown-rot, but left only a distinct frost-line. Diameter of tree, 11 inches.

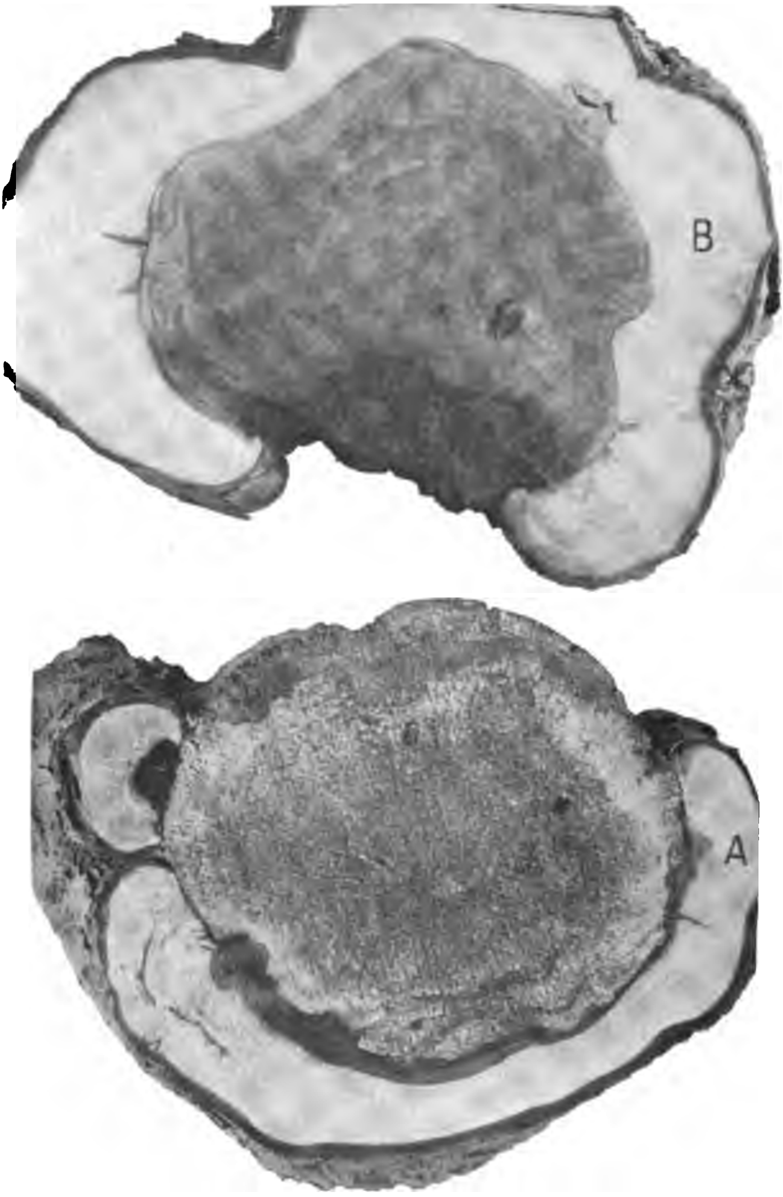

Plate XIX.— Sections near Ground-line of two Crown-rotted Trees. Shows also, distinct frost-lines and heart-wood rot. A, Maiden Blush, 11 inches in diameter; B, Double Rose, 13½ inches in diameter.

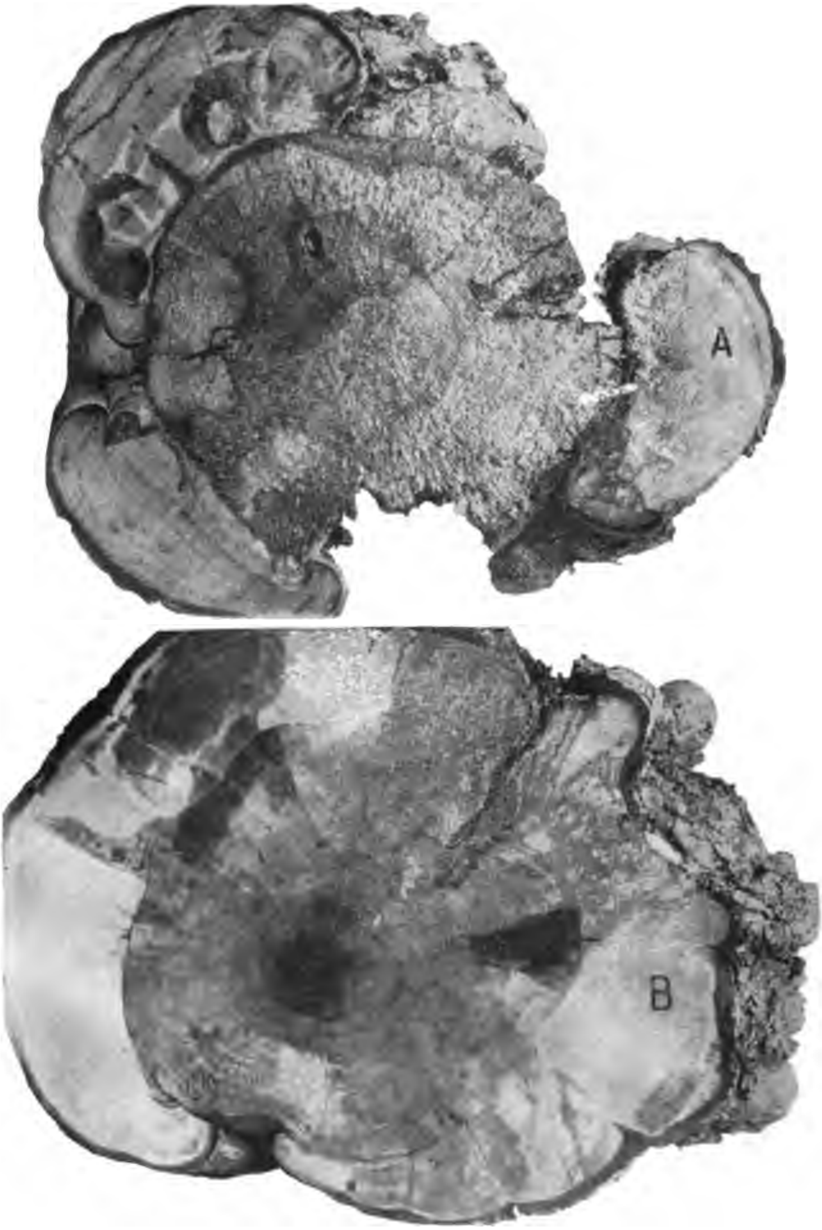

PLATE XX.—SECTIONS OF TWO CROWN-ROTTED TREES, SHOWING FROST-LINES AND HEART-WOOD ROT.

A, Hubbardston, 14 inches in diameter; a Pleurotus was growing from decayed wood near the ground. B, Gideon Sweet, 16 inches in diameter.

Headden says,* "There is no resemblance between our corroded crowns and the King disease, known as Collar rot," they are probably the same disease.

CRITICAL SUMMARY OF THE PRIMARY CAUSES OF CROWN-ROT.

There are, then, three distinctly different primary causes put forth by these various observers in accounting for Crown-rot — parasitic organisms, arsenical poisoning and low temperatures.

PARASITIC ORGANISMS.

Those holding to the idea that parasitic organisms are primarily responsible for this trouble base their conclusions largely upon circumstantial evidence. Nothing in the publications by Cavara, Aderhold or Wilcox, referred to above, can be considered proof that the fungi discussed are other than saprophytes, or at most wound parasites. Neither Cavara nor Wilcox records inoculation experiments. It seems probable that Wilcox's "root-rot" is Crown-rot with the presence of his *Clitocybe parasitica*. Aderhold tried some infection experiments, but from them it is more logical to conclude that the fungus was very remotely, if at all, connected with the production of discoloration in the roots of his nursery trees.

Although von Schrenk appears to have gotten some positive results with *Thelephora galactina* as a parasite of apple-tree roots, the indicated distribution and characteristics of the disease make it possible to assume that *T. galactina* is perhaps a wound parasite gaining entrance to the wood through frost or other injuries. The suggestion by Whetzel, that the "fire-blight" Bacillus may cause the King disease or Crown-rot, probably belongs in the same category.

ARSENICAL POISONING.

It stands to reason that, when arsenical sprays are applied to fruit trees for years, arsenic will accumulate in the soil

* In a reply to Ball on "Arsenical poisoning of fruit trees," in the *Journal of Economic Entomology*, 2: 243. 1908.

beneath, but it remains to be shown that such arsenic, though it may become soluble in soils, injures or kills the trees. Neither the association of a wounded tree and some fungus nor an injured tree and arsenic are certain indications that either the fungus or arsenic has any causal relation to the injury of the tree.

Headden has shown by a number of analyses that considerable quantities of arsenic are present in the soil under some sprayed fruit trees, that crown-injured trees contain arsenic, that lead arsenate is appreciably soluble in dilute salt solutions, that lime arsenite goes into solution in the presence of sulphate of lime and that potted herbaceous plants died after the application of from .05 to .5 gram of "sodic arsenite." But he has failed to show that arsenic is not present in uninjured, sprayed fruit-trees, whether the arsenic in the soil and trees is present as arsenates or arsenites, that arsenates or even arsenites are poisonous to fruit-trees when absorbed by their roots, if poisonous what amounts become injurious, how poison absorbed by tree roots can discolor or injure the *heart-wood* before discoloring the alburnum and cortex, and whether the arsenic was absorbed through the bark of the roots near the trunk or through the usual channels (root hairs) at the periphery of the root system, some distance from the trunk.

It cannot be taken for granted that the arsenic is present in the soil as an arsenite, nor that an arsenate is poisonous to fruit trees, for Pfeffer[30] says "Arsenious acid is extremely poisonous, whereas many, both of the higher and of the lower plants, can withstand large doses of arsenic acid and can accumulate large quantities of arsenic when supplied to them in this form," while F. Czapek[31] says that traces of arsenic are nearly always present in soils and may therefore be absorbed by plant roots. Though it has been shown by Nobbe, Baessler and Will[32] that some herbaceous plants and some

[30] Pfeffer's Physiology of Plants, 2nd revised ed., translated by A. J. Ewart, Vol. I, p. 438.

[31] Biochemie der Pflanzen. Vol. II, pp. 862–63. 1905.

[32] Untersuchung über die Giftwirkung des Arsens, Blei und Zink im pflanzlichen Organismus. *Landw. Vers. Stat.*, 30: 381–423. 1884.

trees were injured or killed in culture solutions to which from 2.1 mgm. to 6.9 mgm. of potassium arsenite per liter had been added, there is some evidence to show that larger quantities of arsenic would not be injurious to those plants when administered to them as an arsenate; for W. Knop[33] says that .05 gm. of potassium arsenate added to one liter quantities of culture solutions would not hinder the normal growth and development of corn plants grown in them from the 10-to-15-leaf stage to maturity, nor would it kill Velcox or a mold. It has also been determined by Hitchcock and Carleton[34] that a 1–10 per ct. solution of sodium arsenite would not retard the germination of *Puccinia coronata* spores.

E. W. Davy[35] found arsenic in herbaceous plants and S. H. Collins[36] grew both barley and tares in 10-inch pots to some of which had been added arsenious and to others arsenic acid, both at the rate of 11 lbs. per acre. No injurious effects are recorded. "Averaging all the results the soil contained 30 lbs. of arsenic per acre, to the depth of eight inches, the grain contained 4 oz. per acre and the rest of the plants 1¼ oz. per acre. Some samples of soil, outside the experiment, taken to the depth of 8 inches, yielded 50 lbs. of white arsenic per acre. It would seem, therefore, " that soil may contain large amounts of arsenic without any suspicion of the fact; (2) barley grown on such soil may also contain large amounts of arsenic." This certainly indicates that comparatively large quantities of arsenic in soils may be innocuous to plants. It was also shown by A. J. Kunkel[37] that arsenic is present in many rocks and waters. Though he failed to find it in animal tissues, he thinks it probable that his method is at fault, for

[33] Ueber die Aufnahme verschiedener Substanzen durch die Pflanze, welche nicht zu den nährstoffen gehören. Abstracted in *Bot. Centbl.*, **22**: 35–36. 1885.

[34] Germination of rust spores in fungicides. Kans. Agrl. Expt. Sta., Bul. 38, pp. 8–9.

[35] Absorption des Arsens durch Pflanzen. *Jahresber. Agr. Chem.*, **3**: 83–84. 1862.

[36] The absorption of arsenic by barley. *Jour. Soc. Chem. Ind.*, **21**: 221–2. 1902.

[37] Beiträge zur Frage des sogenannten normalen Arseniks. *Ztschr. physiol. Chem.*, **44**: 511–20. 1905.

A. Gautier[38] had previously shown that arsenic is normally present in animal bodies, especially in epidermal structures. His findings have also been verified from the biological standpoint by M. Segale,[39] who determined the presence of arsenic in animal tissues by means of reactions induced by *Penicillium brevicaule* when transferred to autolized tissue.

Now, in view of these citations and since Headden's descriptions and plates so closely resemble the ordinary cases of Crown-rot, affecting trees *alike* in both sprayed and *unsprayed* orchards, and since some old orchards in this State (which have been sprayed with arsenic ever since spraying was invented) often have only Crown-rot scars dating back six to fourteen years, and look thrifty now, we either must conclude that we have two very similar diseases due to two different causes, or that there was an unwarranted conclusion drawn, regarding the relation of the arsenic found, to the injury of the trees. The latter seems more plausible, for herbaceous plants about the bases of the affected trees grow *abundantly* and *normally*. It would seem that high winds and low temperatures of Colorado may account for the crown and root-injured trees described by Headden, even though arsenic was found in them.

LOW TEMPERATURES.

The majority of writers on Crown-rot seem to agree that it is caused by low temperatures in connection with certain other factors. From the literature reviewed, it seems quite evident that a certain combination of factors causes injury mostly to underground parts, and that other combinations affect mainly the aerial parts. It appears likely that the time relation, of a severe cold period, to a certain vegetative

[38] Arsenik kommt normaler Weise im thiersichen Organismus vor und ist besonders in den ektodermalen Organen localisirt. *Ztschr. physiol. Chem.*, **36**: 391–97. 1902.

[39] Untersuchungen über das Vorhandensein von Arsen in den normalen Geweben vermittelst der biologischen Methode. *Ztschr. physiol. Chem.*, **42**: 175–80. 1904.

stages of a tree, and the presence or absence of a ground covering determine the place and severity of the effect.

Why roots may be especially susceptible.— Sorauer[40] says the reason that the roots of many trees are killed during more or less severe winters, while the aërial parts are often uninjured, is because of the difference in the relative maturity of root and branch tissues at the arrival of winter. Cambial activity begins first at the distal ends of twigs and, as conditions become more favorable, progresses down to the stem and roots. On the other hand, growth and development generally continues much later in the roots than in the branches. Von Mohl is said to have found that cherry twigs had begun development in April while the root-wood cells of the previous season had not yet finished their development. Owing to these differences in tissue development of root and branch, the former is made up mainly of large cells, characteristic of spring wood. That character of root-wood cells, in addition to their immaturity at the approach of winter, is said to make roots more susceptible to injury than other parts. The leaves of root-injured trees, though developing normally in spring, are found to sudenly turn yellow in summer; often followed later by the death of the tree. In case the injury is confined largely to the aërial parts, it seems probable that either the roots were protected in some way, during the excessive cold period, or the low temperature came after the root-wood had matured sufficiently to be resistant. On the other hand, early, short cold-snaps may injure young shoots but fail to penetrate deeply enough to affect the roots or crown. The publications by Taft, Green and Ballou, Waite, Eustace, Selby (Bulletin 192) and Morse, reviewed above, are of this type.

Suggestive experimental evidence.— The observations and interpretations by Waite and by Morse come nearer the experimental results obtained by P. Sorauer[41] than the others, though

[40] Pflanzenkrankheiten. 3rd ed. Vol. 1, pp. 561–64. 1909.

[41] Experimentelle Studien über die mechanischen Wirkungen des Frostes bei Obst- und Waldbäumen. *Landw. Jahrb.*, **35: 469–525. 1906.**

Morse's explanations of the cause of crotch-injury violate certain physical laws.

To obtain definite information upon the question of frost-injury, young fruit and forest trees were subjected to induced low temperatures in a large double-walled cylinder, by Sorauer. On a potted sweet-cherry tree exposed in May to —7° C. over night, all except the youngest leaves were killed and browned. An odor of roasted cherry wood was noticeable during the first week after removal from the freezing apparatus.

The fibro-vascular bundles, of the venation in older leaves, were often brown, while the intercostal regions were normally green. Hard-bast elements were the first to become browned, followed by the browning of the epidermis-cell contents. The smaller spiral vessels were browned before the larger ones.

The most susceptible region on a trunk or limb was found to be at the points of origin of twigs or branches. A section through a branch at the origin-point of a spur or side-branch shows that the whole of the normally excessive cortical parenchyma was browned and cleft at a number of places. The cambial zone had its cambium mostly uninjured, but both the young wood and bast cells on either side were browned. The wood cylinder, where it branches off from an axis, has its wood-cell bundles much separated by medullary rays which in the frozen tree had become browned, thus leaving only narrow ribbons of living wood sandwiched in between browned rays and the dead pith and cortex. The pith and wood cylinder of the *axis* were uninjured, though its rays near the spur had become browned. The small groups of primitive xylem cells in the outer parts of the pith were also browned. The effect on the one-year-old parts of branches was decidedly different. The injury was generally more pronounced on one side than on the other, forming frost-blisters on the bark. The pith was split, leaving a hollow center surrounded by collapsed, browned cells, though the other pith cells seemed mostly uninjured. Separation always occurred at the middle-lamellæ.

A section through the transition region from the one-year-old to the spring growth revealed some interesting facts. The

wood cylinder is small and was found to be split at the thick medullary rays. The fibro-vascular bundles were completely surrounded by browned parenchyma and isolated from the uninjured cambium and but slightly browned bark. The pith was not affected. This state of things could be followed down into the year-old twig, where, however, the wood cylinder was not separated from the bark.

Radial clefts in the wood and cortex are said to be caused by the tangential contraction of the twig's tissues. Since the wood and cortex-parenchyma cells can distend but little, ruptures occur at the middle-lamellæ of the medullary rays. The separated wood-ray cells were browned, but the bark-ray cells seemed uninjured and soon closed their clefts. The cambium cells, however, distend readily and were therefore generally found intact and unaffected. These observations are thought to show that differing tissue-tensions and not ice-formation are the causes of clefts and cracks.

Sour-cherry trees given the same treatment were not affected in exactly the same way. Fewer and smaller clefts were formed, a stoppage of the vessels with gum seemed to occur. It is thought the excessive formation of gorged, imperfect cells in the greatly reduced growing regions of a much-injured tree may lead to a disorganizing gummosis of the abnormal tissues.

The cleft formation occurs also in pear and apple branches when subjected to the freezing treatment. The same differences were observed between the effect in the terminal and basal ends of branches as described for sweet cherry. To determine how far low-temperature injuries can extend down the wood of an externally unaffected twig, an apple-tree shoot, having a new spring growth of 4—6 cm., was subjected to —6° C. overnight. The spring wood was entirely killed and the wood cylinder of the one-year-old part as browned down 15 cm. The dormant buds were not killed but their spiral vessels were browned. Some of the branches of a five-year-old pear seedling were subjected to a temperature of —7° C. over night. Most of the leaves turned black, many having frost-blisters.

In the petioles the vascular bundles, the collenchyma cells and the inner cortex were browned. *The branches were injured more on one side than on the others.* The pith was white except some scattered starch-bearing cells, which had browned contents. The bast cells of the cortex were unaffected, while the cells immediately surrounding them were much browned. Only a few small clefts were found between collenchyma and parenchyma cells. It seems, in fact, that when any clefts result they generally occur where different types of tissue join.

The tension differences caused by low temperatures between two or more types of adjoining tissues are said to be the cause not only of cleft formation in the softer, young tissues but also of the splitting of large tree trunks. In case of young twigs, the bark contracts so much more than the wood cylinder that it may either crack open when the temperature is very low, or mechanically injure tissues in the cambial region, when the cold is less severe. The cortical-tissue cells are distended tangentially to a greater or less degree and owing to their imperfect elasticity often remain at least partially distended after moderate temperatures return. The net result may have been sufficient to make the bark too large for the wood cylinder and result in tangential clefts, or at least to lessen the bark pressure enough to cause *abnormal thickening* at certain places, both of which may often be observed on frost-injured fruit trees. At a branching node or at the junction of two seasons' growth on a twig, the same forces may result in the thickening of the medullary rays.

OTHER POSSIBLE CONSEQUENCES OF FROST-INJURIES.

The various cankers.—Frost-injuries seem, therefore, to occur most readily at crotches and other branching points of limbs and twigs, as has also been observed by Morse and others. In view of Sorauer's observations on the effects of frost-injury, under control conditions, and the fact that the same varieties are reported susceptible to canker as are easily frost-injured and that cankers are usually said to spread during winter and early spring makes it appear plausible that Sphæropsis, Numularia, Glœosporium, Cytospora and Bacillus

cankers of fruit trees may be at least partially if not wholly due to low temperatures. The fact that in some cases a large number of successful wound-inoculations were made does not preclude it, because that only argues for a wound-parasite. Probably some of these organisms can extend a canker wound, and to some extent determine its final characteristics, but it is certainly a striking fact that practically all such cankers attributed to parasitic organisms are located at frost-susceptible places and generally active but one year. It appears at least equally probable that such cankers are due to the death of certain tissues, as was shown by Sorauer. These canker organisms are confined largely to the bark, and yet it is often stated that girdled branches die from their activities. It may well be that a short girdle of bark removed from a healthy fruit-tree branch would not kill it, for R. Hartig[42] says that after removing six-foot girdles of cortex from fifteen 120-year-old Scotch pines, he found some still alive six years later; and on girdling 27 species of trees, F. F. R. Channer[43] observed that five species died, ten others were much injured, while twelve species lived. At any rate, it seems plausible that a girdled apple-tree branch may die because of its frost-injured wood rather than on account of the organisms present in its dead girdle of bark. Finding discolored heart-wood at some distance from a canker on an apple-tree branch does not necessarily mean that the canker fungus discolored it, as interpreted by Hasselbring, for it more likely signifies that the tree was winter-injured.

Some cherry-tree diseases.—In referring again to the above review of Sorauer's article, it is seen that the origin-point of branches and spurs of cherry are the first parts to be injured by low temperature and that in the sour cherry the lumina of the conducting vessels had become clogged with gum. In

[42] Diseases of Trees. Translated by Sommerville and Ward. P. 249. 1894.

[43] *Indian Forester*, **31**: 376-8 (1905); abs. in *Expt. Sta. Record,* **17**: 670. 1906. See also "Effects of annular decortication on peaches" by F. Calzolari and Manaresi, *Exp. Sta. Rec.* **21**: 439. 1909.

a later publication[44] he holds that the dying of cherry trees in the Rhine districts, so elaborately discussed by Frank and others and attributed to *Valsa leucostoma,* is primarily due to the above type of winter-injury. Sometimes many branches or even whole trees die. The bark and wood of the affected trees had the browned appearance typical of frost-injury. Anderhold and Wehmer are said to have shown that *Valsa leucostoma* is only a wound parasite and may only vegetate on much-weakened trees, and later Lüstner is said to have shown that it would only attack practically dead parts of cherry trees. It is therefore thought that the planting of frost-resistant varieties is more important than the careful destruction of the fungus-infected dead twigs. Sweet cherry is often similarly affected in this country. Some such cases became evident late this summer in an orchard of this Station. Several large trees died from the top downward.

Sour-cherry trees were affected again, this autumn, in the manner described in 1899 by F. C. Stewart,[45] of this Station, under the head of "Leaf scorch of cherry." The affected branches are usually lateral, and seem generally to have discolored wood, as observed by Stewart. Later he reported[46] that though the "season of 1900 was drier than that of 1899, there was none of the cherry-leaf scorch such as occurred in 1899." In 1900 branches on the leaf-scorched trees were found injured, many buds dead, and the remaining fruit-pedicels were unusually short. Probably Sorauer's experiments and observations mentioned above sufficiently account for the primary cause of these cases of suddenly drying normal leaves. But as in all types of winter-injury, in which trees are not killed outright, the availability of water may determine the time at which the injury becomes apparent, so in these cases the drought of late summer marked the branches most frost-injured by drying their leaves.

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[44] Pflanzenkrankheiten, I, p. 553. 1909.
[45] N. Y. Agrl. Expt. Sta. Bul. 162, pp. 17[illegible]-176. 1899.
[46] N. Y. Agrl. Expt. Sta. Bul. 191, pp. 309--16. 1900.

A peach-tree disease.—In this connection it may be well to review briefly a case of "Die back of the peach trees," discussed by F. M. Rolfs,[47] where it is claimed to have been shown that *Cytospora rubescens* is an active parasite of the twigs, limbs and trunks of peach, plum, apricot and cherry trees. "Alternate freezing and warm periods" seem to favor the progress of the injury on peach shoots, often killing them back two to fifteen inches during January and February. "Infections on the older branches during the winter and early spring months produce oblong wounds extending up and down the stem."

"During the spring and summer months the foliage of infected twigs frequently wilts suddenly and takes on a brown, blighted appearance." "Large limbs or even whole trees in different stages of vegetation and at different times of the year die suddenly."

These observations can certainly be interpreted in another way, for they appear primarily to be winter-injury.

Some other possibilities.—It is well not to ride a good horse till it becomes a hobby, but there are two other matters that may be considered in this connection; namely, the little apples of this season, and the Bacillus blight of pear and apple. Perhaps it will prove profitable to find out whether such fruit-spurs and twigs, bearing clusters of small apples, have been winter-injured. A cursory examination of them has shown the presence of some browned cortical tissues around the bases of some spurs, and often a more or less distinct brown line at the transition of last year's into this year's wood. It is generally considered that plant lice and drought are the causes of this type of little apples, but that foregone conclusion may better be oriented somewhat in relation to this other probable factor.

The virulence and destructiveness of the twig blight Bacillus have been so often observed and discussed that it has become a commonplace, but its manner of infection and of

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[47] *Science*, N. S., **26**: 87–9. 1907.

advance in the cambial zone are yet shrouded in mystery, though prolific theoretical explanations have been given. Is it possible that the occurrence of a "fire blight" epidemic is fundamentally dependent upon how the trees came through the previous winter rather than upon the weather of spring and early summer? Is "fire blight" only the sudden drying of such twigs as were winter-injured to a certain degree, at their "branch rings" of normally excessive cortical and medullary tissues?

WINTER-HARDINESS OF TREES.

There is not much definite to be said regarding hardy and susceptible varieties as related to Crown-rot or other frost-injuries, because all observations have been too limited and fragmentary. If trees are to be grown in regions of deep, all-winter snows, the winter-hardiness of roots is not as important as that of the trunks and branches; however, in regions of uncertain snows the hardiness of roots must be considered first.

As regards varieties and stocks.— Nearly all of our most desirable varieties of winter apples have been reported, by some one or other, as liable to winter-injury and the numerous ills which follow in its wake. Though, of course, some are more winter-hardy than others. Macoun's[48] report on "The relation of winter apples to hardiness of trees" shows that 79 per ct. of all winter-killed trees are winter varieties. He suggests that the ancestors of seedlings be short-seasoned varieties. Early-maturing varieties were also found more resistant by C. Baltet.[49] Emerson's suggestion that the early maturity habit is often more important than constitutional hardiness to frost, may prove of value. It seems to be still an open question to what extent, if at all, a stock of an habitually early variety may influence the ripening habit of a scion from a late-

[48] *Canad. Hort.*, **29**: 291–2. 1906.
[49] De l'action du froid sur les végétaux pendant l'hiver 1879–80. *Mem. Soc. Nat. Agr. France,* **127**: 1–340. 1882.

maturing variety. The histology of grafts has been more carefully studied[50] than the physiologic relation of stock and scion, though the latter is probably of more importance. Generally, only the morphological and color modifications are noted. We have numerous examples of visible end-reactions which seem to be due to certain stock-scion relations; such as result in graft-hybrids, as shown by H. Winkler,[51] and others transmitting albinism from the stock to the scion, as is often shown by grafting a green variety of *Albutilon thompsoni* on an albino stock of the same species. But the transmission of invisible qualities from one symbiont to another has but seldom been investigated, though it probably always occurs more or less. It has been shown by E. Strasburger[52] that the poisonous atropin from a *Datura stramonium* scion was transmitted to the tubers of a potato stock upon which it was grafted.

An interesting summary and extension of this question is given by Herse.[53]

As regards soil and moisture.—Some differences of observation and opinion are found as regards the character and location of land which is conducive to winter-hardness of fruit trees. According to some authors, trees on high, dry knolls, and according to others, those on low, wet places are most susceptible to winter-injury. A distinction should, perhaps, be made between injury to *tops* and injury to *roots*, though they sometimes occur at the same time. From the observations by others it seems that aerial parts are more often injured in low, wet places (probably because the injurious temperature came when the wood was immature),

[50] F. Schmitthenner. Verwachsungserscheinungen an Ampelopsis- und Vitis- Veredelungen. *Ztschr. Pflanzenkrank.*, **18**: Beigabe I, pp. 11–20. 1908. See also Ueber den Einfluss des Reises auf die Unterlage. C. Mikosch. Wiesner-Festschrift. pp. 280–6. Wien. 1908.

[51] Solanum tubingenese, ein echter Pfropfbastard zwischen Tomate und Nachtschatten. *Ber. deut. bot. Ges.*, **26A**: 595–608. 1908. *Ztschr. Bot.*, **1**: 315–45. 1909.

[52] Ueber Verwachsungen und deren Folgen. *Ber. Bot. Ger.*, **3**: xxiv–xl. 1885.

[53] F. Herse. Beiträge zur Kenntniss der histologischen Erscheinungen bei der Veredelung der Obstbäume. *Landw. Jahrb.*, **37**: Erg. 4: 71–136. 1908.

while roots seems more often affected on high, dry land. The observations by Nelson in Wyoming and Emerson's experiment in Nebraska are illustrations of the latter. But from recommendations by Clinton it seems that in Connecticut the highlands are to be preferred for orchards. Emerson also advised the use of high ground in connection with cover crops to induce early maturity.

My observations seem to indicate that the crowns and roots of apple trees were more often injured on rather thin, dry land. One reason seems to be that the specific heat of dry soil is less than that of wet soil, and that therefore its temperature changes more rapidly and cold penetrates more deeply than in wet soil. Sod orchards seem to have been less winter-injured on both roots and branches than cultivated ones. Paddock and others record the same for Sphæropsis cankers, and it is common knowledge that "fire blight" occurs more generally in cultivated orchards. But in regard to the Crown-rot-type of winter-injury, it seems that that occurs most readily in orchards after the breaking of the sod, though on thin land sod cannot always prevent it. From the few cases observed it seems that it is not tillage, as such, that induces root-injuries, but the change from sod to tillage. Probably the unaccustomed amounts of nutrients and moisture available to sod trees when they are tilled, or to cultivated trees when they are unusually fertilized, stimulate them to excessive and late growth which may result in winter-injury. As suggested before, soils permitting the formation of deep, extensive root-systems seem to enable trees to recover much more readily when they have been crown or root-injured. Hartig[54] suggests that a deep root-system conducts heat upward during frozen winters. Craig and others have also observed that Crown-rotted trees generally have their deepest roots unaffected.

PREVENTIVE MEASURES IN GENERAL.

The preventive measures generally advised are: Early, thorough cultivation, followed by a cover crop in midsummer; if

[54] Diseases of Trees; p. 283.

possible use hardy, short-seasoned seedlings or crabs for stocks, and plant ordinary nursery trees deep. S. T. Maynard[55] concludes from a ten-year test of Williams' Favorite grafted upon Siberian crab, "That the Siberian crab apple tree does not make good stock upon which to graft the varieties of our larger apples."

Cultivation appears always to pay[56] even though some trees may be lost by it. When a sod orchard is to be cultivated, it may be well to plow it in autumn, after the leaves have fallen, so that growth may start early in the spring.

Cover crops are not always used, even by our best orchardists, and often without harmful results. Probably the necessity for a cover crop depends somewhat upon the season and perhaps more upon the type of soil, the age of the trees and their locality. All preventive measures may fail when a summer season is such as to compel very late growth and unusually cold weather comes early; even sod orchards are severely injured at such times.

CONCLUSIONS.

The need for a long, thorough investigation of Crown-rot and its attendant ills is evident. It seems more or less destructive throughout the best apple-growing States. The relations of low têmperatures,[57] arsenical poisons and the various organisms, to cankered and Crown-rotted trees, are not known sufficiently, nor is it definitely understood how the different types of soil are related to root-injuries and canker-injuries, and what relation low temperatures have to enzyme-action. The mutual influence of stock and scion, when known, may help the problem. And, as a result of such investigations, sane measures of orchard management to increase the winter-hardiness of our fruit trees may be materially advanced.

[55] Mass. (Hatch) Agrl. Expt. Sta. Bul. 17: 36–7, 41.

[56] U. P. Hedrick. A comparison of tillage and sod mulch in an apple orchard. N. Y. Agrl. Expt. Sta. Bul. 314, 1909.

[57] Some work on the relations of arsenites and arsenates, and of low temperature (with its principal secondary factors) to Crown-rot, will be started in the near future by the writer.

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REPORT

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TABLE OF CONTENTS.

REPORT OF CHEMICAL DEPARTMENT.

A VOLUMETRIC METHOD FOR THE DETERMINATION OF CASEIN IN MILK.*†

L. L. VAN SLYKE AND ALFRED W. BOSWORTH

SUMMARY.

A given amount of milk, diluted with water, is made neutral to phenolphthalein solution by addition of a solution of sodium hydroxid. The casein is then completely precipitated by addition of standardized acetic acid; the volume of the mixture is made up to 200 cc. by addition of water, thoroughly shaken and then filtered. Into 100 cc. of the filtrate a standardized solution of sodium hydroxid is run until neutral to phenolphthalein. The solutions are so standardized that 1 cc. is equivalent to 1 per ct. of casein when a definite amount of milk is used. The number of cubic centimeters of standard acid used, divided by 2, less the amount of standard alkali used in the last titration gives the percentage of casein in the milk examined. When one uses 17.5 cc. (18 grams) of milk, the amount used in the Babcock milk-fat test, the standard acid and alkali solutions are made by diluting 795 cc. of tenth-normal solutions to 1 liter. By using 22 cc. of milk, tenth normal solutions can be used directly; or by using 20 cc. of milk and tenth-normal solutions, adjustment is made by multiplying the final result by 1.0964.

The method usually gives results within 0.2 per ct. of those obtained by the "official" method.

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INTRODUCTION.

In 1892 there was worked out in the chemical laboratory of this Station a method for the determination of casein in cow's milk.[1] This method, after careful trial by the Association of Official Agricultural Chemists, was adopted as "official."[2] It was realized that the method was adapted only for use in well equipped chemical laboratories and in the hands of trained chemists. Beginning 16 or 17 years ago, unsuccessful efforts were made here at different times to devise a simple, direct, volumetric method, requiring less apparatus, time, manipulation and skill. Several attempts have been made by others to find such a method, among which we mention the following. (1) Estimation of casein: a preliminary study.[3] (2) Quantitative estimation of casein.[4] (3) A new method for the determination of casein.[5] These and other proposed methods are open to several practical objections.

A method that is satisfactory in all respects for finding the amount of casein in milk should have the following characteristics: (1) It should be accurate; (2) its operation should require only a few minutes; (3) it should effect economy of time when several determinations are made at the same time; (4) the apparatus and materials used should be simple, readily obtainable and inexpensive; (5) the manipulations should be simple, such as can be acquired with a minimum amount of previous training; (6) the mechanical work required should not be needlessly tiresome.

In making a study of the accuracy of the results given by the method of Matthaiopoulos, it was found that a reconstruc-

[1] N. Y. Agrl. Exp. Sta. Ann. Rept., **12**:487–496 (1893); *Jour. Amer. Chem. Soc.*, **15**:635–645.
[2] U. S. Dept. Agr., Chem., Bul. 51.
[3] V. H. Arny and T. M. Pratt. *Amer. Jour. Pharm.*, **78**:121–128 (1906).
[4] T. B. Robertson. *Jour. Biol. Chem.*, **2**:328–334 (1906).
[5] G. T. Matthaiopoulos. *Ztschr. Analyt. Chem.*, **47**:492–501 (1908).

tion of its details could be easily utilized in devising a method of equal accuracy but of much greater simplicity and rapidity.

The method which has been thus worked out is, in brief, as follows: A given amount of milk, diluted with water, is made neutral to phenolphthalein by addition of a solution of sodium hydroxid (caustic soda). The casein is then completely precipitated by addition of standardized acetic acid; the volume of the mixture is made up to 200 cc. by addition of water and then filtered. Into 100 cc. of the filtrate a standardized solution of sodium hydroxid is run until neutral to phenolphthalein. These solutions are so standardized that 1 cc. is equivalent to 1 per ct. of casein when a definite amount of milk is used. Therefore, the number of cubic centimeters of standard acid used, divided by 2, less the amount of standard alkali used in the last titration gives the percentage of casein in the milk examined. The operation usually requires 12 to 15 minutes when apparatus and solutions are at hand in convenient forms for ready use; several determinations can be carried on simultaneously with much relative economy of time.

This method is based upon the following well-known facts: (1) Uncombined casein is insoluble in milk-serum, or water, or very dilute acids.[6] (2) It is acid in properties and combines with alkalis to form definite chemical compounds, which are neutral to phenolphthalein.

Of the total amount of acid used in the process of precipitating casein, a portion is taken to set casein free from combination, thus forming a soluble neutral salt and an insoluble compound (free casein) possessing the properties of an acid; and, on filtration, this amount of acid, as free casein, is removed from the mixture. The balance of the acid used in the process is accounted for in the filtrate on titration with alkali. Therefore, the difference between the total amount of

[6] N. Y. Agrl. Expt. Sta. Tech. Bul. No. 3, pp. 105–6; *Amer. Chem. Jour.* **38**:409–10.

acid used and that accounted for in the filtrate by titration with alkali represents the amount of acid corresponding to the casein present in the milk examined.

Since one gram of free casein neutralizes 8.8378 cc. of tenth-normal sodium hydroxid (or 1 cc. of tenth-normal sodium hydroxid equals 0.11315 gram of casein),[7] we have a definite basis for estimating the amount of casein in any given case, when we know the amount of alkali it neutralizes.

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[7] *Ztschr. Analyt. Chem.*, 47:495.

Plate XXI.— Apparatus Used in Volumetric Determination of Casein in Milk.

DESCRIPTION OF METHOD.

The various details of the method will now be taken up for description and discussion under the following heads: (1) The required apparatus, (2) the necessary solutions, and (3) the operations performed in applying the method. Since the method is intended for the use of many who have not had much, if any, training in chemical work, the description is made to cover many details which are matters of common familiarity to those who have had laboratory training in volumetric quantitative work.

For convenience of use in dairy schools and places where the Babcock test for fat is employed, we have based the description of the method upon the amount of milk used in that test, 17.5 cc. or 18 grams. The adaptation of the method to the use of 20 cc. and 22 cc. of milk is also given for the convenience of those preferring such modifications.

APPARATUS.

(1) Two *50 cc. burettes,* accurately graduated to $^1/_{20}$ cc. When many determinations are to be made, time can be saved by using automatic burette-fillers, such as are in common use in chemical laboratories, dairy schools and creameries.

(2) *Flasks,* so-called *volumetric, holding 200 cc.,* provided with a mark at the exact 200 cc. point. Two of these are needed for each determination made in duplicate. For greatest convenience, we prefer flasks having necks 4½ to 5 inches long and an inside diameter of about ¾ inch, with the 200 cc. mark 1½ inches up the neck above the globe-shaped portion of the flask.

(3) One *milk-sampling pipette,* accurately graduated at 17.6 cc. and made to deliver 17.5 cc. (18 grams) of milk. This is the regular form of pipette used in the Babcock test for fat in milk.

(4) *One 100 cc. pipette* provided with a mark to permit the delivery of exactly 100 cc.

(5) *One small pipette* with rubber bulb (so-called dropper), provided with a mark at the 1 cc. point.

(6) *Breakers or cups* holding 200 cc. or more. Ordinary white porcelain tea-cups, or white granite-ironware cups answer the purpose.

(7) *Funnels,* glass or granite-ironware, 3 to 4 inches in diameter.

(8) *Filter-paper* cut round, 6 to 7 inches in diameter. In their place one can use fine linen cloth cut in proper size and shape. These have the advantage of permitting repeated use, being washed always after use.

(9) *Measuring-cylinders,* accurately graduated and holding 1,000 cc.

SOLUTIONS.

(1) *Sodium hydroxid.* This solution may be made most conveniently by preparing a regular tenth-normal solution and then diluting 795 cc. of this to one liter. In such a solution, 1 cc. corresponds to 0.09 gram of casein or 1 per ct. when one takes 9 grams of milk for testing. In actual practice, we take a 17.5 cc. (18 grm.) sample of milk, but in the final part of the test use only one-half of the solution obtained.

Alkali solutions made from alkaline tablets, such as are often used in dairy work for determining acidity of cream, milk, whey, etc., do *not* give satisfactory results in this test for casein.

The simplest method of preparing the alkali solution is to purchase from a reliable chemical supply-house sodium hydroxid, of the quality known as "strictly chemically pure," put up in sealed, glass-stoppered bottles, each bottle containing exactly 40 grams. The entire contents of the bottle, dissolved in one liter of water, make a *normal* solution; and 100 cc. of this normal solution, diluted with water to one liter, gives the tenth-normal solution, 795 cc. of which diluted to one liter makes the strength of solution desired when using 17.5 cc. of milk for the test under the conditions stated above.

In making standard solutions, pure distilled water should be used if possible, or else as pure rain-water as can be obtained.

Instead of purchasing the solid sodium hydroxid one can obtain a normal solution of the alkali directly from chemical supply-houses and then dilute this in the manner already indicated.

Solutions of sodium hydroxid, when exposed to the air, absorb carbon dioxid and change in strength so as to become unreliable; they should, therefore, be kept carefully in tightly-stoppered bottles.

(2) *Acetic acid.* This solution is made so that a given amount of it will exactly neutralize the same amount of the standard alkali solution of the strength above indicated. The simplest, but not the cheapest, way of preparing this solution is to purchase a *normal* solution and dilute 1,000 cc. of this to 1,260 cc. (or 795 cc. to 1,000 cc.).

The following method of preparing standardized acetic acid is the one commonly used in laboratories: Concentrated acetic acid, 99 per ct. or more pure, is employed. In preparing considerable amounts, one measures out about 12 cc. and dilutes to 2 liters of stock solution with pure, soft water (preferably, distilled). This makes a solution approximately tenth-normal, but somewhat too strong. One takes 25 cc. of this solution, adds two or three drops of phenolphthalein solution and then runs in from a burette the standardized alkali until the neutral point is reached, when the solution becomes faintly but distinctly pink in color, the coloration remaining for some time. The amount of alkali solution thus required is read from the burette. Suppose, for example, that 25 cc. of the diluted acetic acid requires 27.5 cc. of alkali. This means that each 25 cc. of acid should be diluted to 27.5 cc. in order to have the proper strength, or each 1,000 cc. of acid solution should be diluted to 1,100 cc. by addition of 100cc. of water. The method of calculation, expressed as a general rule, may be stated as follows: To find the amount of standard acid, multiply the

number of cubic centimeters of standard alkali required to neutralize a given amount of acid by 1,000 and divide the result by the number of cubic centimeters of acid used in titration. Of course, a smaller amount than a liter may be used for dilution, so long as the rate of dilution is kept in the proper proportion. After having once found the strength of the stock solution, any desired amount of this can be made to the proper dilution at any time.

When an acetic acid solution is to be kept on hand for some time, it is desirable to add a small amount of pure mercuric chlorid (corrosive sublimate), for one liter about as much as will lie in a thin layer on a silver dime, in order to prevent change of strength by fermentation. The solution should be kept in tighty-stoppered bottles.

For those who have had no experience in making standard solutions or who lack requisite facilities, it is recommended that *normal* solutions be obtained from some reliable chemical supply-house. The address of the most convenient dealers can be obtained from the agricultural college or experiment station.

(3) *Phenolphthalein solution.* This is made by dissolving one gram of dry, powdered phenolphthalein in 100 cc. of 50 per ct. alcohol. Some samples of phenolphthalein are quite acid and it is well to add to the prepared solution a few drops of dilute alkali until the solution acquires a slightly pinkish color.

PERFORMING THE OPERATION.

(1) *Measuring and diluting sample of milk.* The milk to be tested is well mixed and a 17.6 cc. pipette filled to the mark and the milk run into a 200 cc. flask. Then one adds about 80 cc. of pure, soft water (preferably, distilled), filling the globe-shaped portion of the flask about half full. In pouring the water in, any milk adhering to the inside wall of the neck of the flask is washed down into the flask.

(2) *Neutralizing the milk.* Add 1 cc. of phenolphthalein solution to the diluted milk and then run into it the alkali solution from a burette, in small portions, shaking vigorously

after each addition of alkali, until a faintly, but distinctly, pinkish shade of color remain even after considerable agitation. Any marked excess of alkali must be avoided.

(a) Preparation of color standard.—We have found that more uniform and satisfactory results in neutralizing can be attained by preparing a color-standard for comparison. Our method of accomplishing this is as follows: About 20 cc. of fresh skim-milk and 80 cc. of water are put into a 200 cc. flask and a small amount of mercuric chlorid added to prevent souring. A few drops of ordinary carmine ink are considerably diluted with water and this is carefully added, a few drops at a time, to the diluted skim-milk until a faint but distinct pinksh coloration appears. This can be more readily and accurately perceived by placing beside the flask another flask half full of uncolored diluted skim-milk. The coloration must be as slight as possible and yet be appreciably distinct when compared with uncolored milk. After the color-standard has been prepared, the flask is stoppered. It is well to keep this standard in a dark place when not in use. With some carmine colors, the pinkish shade in the milk deepens on standing, especially when exposed to light, and with others it may fade. If at any time a deeper shade is observed, the proper shade can be reproduced by slight dilution with skim-milk; in case of fading, the additon of one or more drops of carmine ink is needed. The object of using skim-milk in preparing a color-standard is to avoid the presence of fat which, in case of whole milk, separates on standing, adheres to the sides of the flask and obscures the color.

(b) Use of color-standard.—In neutralizing a sample of milk, the color-standard is placed beside the sample under examination for constant comparison after each addition of alkali. The flasks should be placed on a white surface and in a good light in order to render more sharp the observation of the coloration. In fresh milks, it is usually found that 3 or 4 cc. of alkali is sufficient to neutralize the milk. In cases where milk is not strictly fresh or where it has been kept

for some time with mercuric chlorid, usually from 5 to 10 cc. or even more may be required. One can usually add 2 or 3 cc. of alkali at the start and then add it in smaller portions, until the milk begins to show signs of neutrality. After that the alkali is added a drop at a time, the flask being shaken and the color being observed after each addition. The operation of neutralizing should be performed only in a good light, sufficiently strong to enable one to observe slight changes of coloration. Persons accustomed to the determination of the acidity of milk, cream, etc., should have no difficulty in observing the proper color point that indicates neutrality. A little experience, especially under proper instruction, will enable one to perform this step with rapidity and accuracy.

(3) *Precipitation of casein.* (a) Addition of acid.—Into the neutralized sample of diluted milk, which should be at a temperature of 65° to 75° F., one now runs from a burette some of the standardized acetic acid, adding the acid approximately in 5 cc. portions and agitating vigorously for a few seconds after each addition. It is usually safe to add about 25 cc. of acid before examining the milk to see if the casein separates in the form of white flakes. After adding 20 to 25 cc. and shaking, the mixture is allowed to come to rest. If enough acid has been added, the casein separates promptly in large, white flakes, and, on standing a short time, the liquid above the settled casein appears clear and not at all milky. If the addition of 25 cc. of acid is insufficient to separate the casein properly, add 1 cc. more of acid and shake; continue the addition of acid, 1 cc. at a time, until the casein is observed to separate promptly and completely on standing at rest a short time. The number of cubic centimeters of acid used to effect precipitation is noted and *this result is recorded as A.*

(b) Influence of temperature.—For convenience of work and uniformity of results, the temperature of the mixture at the time of the addition of acid may be between 65° and 75° F. Under these conditions, we have found that in most of the milks with which we have worked 30 cc. of acid gives satisfactory results. In some cases, especially with the milk of

cows far along in lactation and high in casein (3.5 to 4 per ct.), we have had to use as high as 35 to 40 cc. of acid. We have seldom found any case in which 25 cc. of acid was excessive. The amount of acid may be 2 or 3 cc. in excess of that required to effect complete precipitation without seriously affecting the accuracy of the results, provided the temperature of the mixture is below 75° F. At temperatures above 75° F., good results are attainable, but care must be taken not to use much excess of acid; and, of course, the higher the temperature, the less will be the amount of acid required for precipitation. Extra care must be used at higher temperatures in regard to the use of any marked excess of acid for the following reason: The higher the temperature, the more easily does casein dissolve in the presence of free acid,[8] the effect being to reduce the results of the test in percentage of casein. In working at temperatures under 65° F., the casein separates more slowly or requires more acid to separate promptly. In case of milk that is much below 65° F., it is well to use for dilution water that is at a temperature of about 80° F.

(4) *Filtration of casein.* After the casein is completely precipitated, pure, soft water (preferably, distilled), is added until the 200 cc. mark is reached and the contents are then vigorously agitated 10 or 15 seconds, in order to make the distribution of acid through the mixture as uniform as possible. The contents of the flask are then poured on a dry filter and the filtrate caught in a beaker or cup. The funnels, filters and beakers or cups should all be dry before being used. It is well generally to allow the filtration to continue until practically all of the liquid has run into the beaker or cup.

(a) Rapidity of filtration.— The usual time of filtration should not exceed 3 to 5 minutes. The rapidity depends upon the temperature of precipitation and the completeness of the separation of casein. In general, the higher the temperature of the mixture when precipitated with acid, the more rapid

[8] N. Y. Agrl. Expt. Sta., Tech. Bul. No. 3.

should be the filtration, other conditions being uniform. In case of insufficient acid, the filtration is slower.

(b) Appearance of filtrate.—The filtrate should be quite clear, though this is not always a sure indication that the right amount of acid has been added to effect complete precipitation and release casein entirely from its combination. Sometimes the filtrate may be clear when not quite enough acid has been added, in which case the percentage of casein found is apt to be low; under such circumstances, filtration is usually slow. In case of milks rich in fat, a slight turbidity may appear, due to fat-globules in the filtrate. The filtrate should be free from all signs of marked turbidity or anything like milkiness. If such a filtrate appears, a new sample of milk should be taken and the operation repeated from the beginning, more acid being used than before. With a little experience, especially under proper instruction, no difficulty should be found in recognizing quickly when the casein is separated so as to give satisfactory results.

(5) *Titration with alkali.* After filtration is completed, one measures 100 cc. of the filtrate with the pipette into a beaker or cup and then from the burette runs into this the standard alkali until a faint, but distinct, pink color remains clearly marked through the solution for half a minute or longer before beginning to fade. The number of cubic centimeters of alkali used is noted and *this result is recorded as B.*

The last portions of alkali must be added carefully, a drop at a time, agitating the mixture well after each addition. The exact neutral point is not perfectly sharp on account of the presence of phosphates, and the appearance of the desired coloration is, therefore, not as sudden and pronounced as might be desired. With experience one should have no difficulty in getting within one drop of the correct amount of alkali. The chief precaution to be observed is to have the same shade and duration of color every time. Thus one should not in one titration add alkali until a deep pink coloration appears, lasting for some minutes, and then in another, a

coloration that disappears within 5 seconds. In the case of milk rich in phosphates, the solution usually grows quite turbid as the neutral point is approached, making it necessary to use more care in observing the color of the end-point of the reaction.

If one desires to make a second titration of the same filtrate, one can use 50 cc. of the remaining portion, multiplying the result by 2 and recording this as *B*.

(6) *Calculation of results.* The calculation of the percentage of casein from (1) the amount of acid used (*A*) in precipitating the casein and (2) the amount of alkali used (*B*) in neutralizing 100 cc. of filtrate, is very simple. *Divide A by 2 and from the result subtract B;* or, expressed as a formula,

$$\frac{A}{2} - B = \text{Per ct. of casein in milk.}$$

Example: One uses 30 cc. (*A*) of acid in precipitating casein and 11.95 cc. (*B*) of alkali in neutralizing 100 cc. of filtrate (one-half of filtrate from the casein precipitate, corresponding to 9 grams of milk). Substituting 30 for *A* and 11.95 for *B* in the formula we have

$\frac{30}{2} - 11.95 = 15 - 11.95 = 3.05$ (the percentage of casein in milk).

(7) *Use of preservatives.* In making a casein determination by this mehod, it is desirable when possible to use milk not more than 24 hours old, which has been kept in a cool place. Milk which is sour or which coagulates on heating can not be used with satisfactory results. However, by adding to fresh milk powdered mercuric chlorid (corrosive sublimate) in the approximate proportion of 1 part to 1,000 or 1,500 parts of milk, and then keeping the mixture at a temperature of 50° F. or lower, we have been able to obtain satisfactory results with milk that had been kept two to three weeks. Milk thus treated should be shaken often enough to keep the fat well incorporated in the body of the milk. The desired amount of mercuric

chlorid may be approximately measured by taking the quantity that will easily lie on the surface of a silver dime for one quart of milk or, more conveniently, the amount held by a 0.22-inch, pistol cartridge-shell ½ inch long, when loosely filled. A stiff wire soldered to such a shell makes it convenient to handle. Commercial mercuric chlorid tablets containing coloring-matter can *not* be used.

(8) *Summary of precautions.* Below we give in outline the special points to be observed with care in performing the operations of the test, assuming that the graduated glassware is accurate and the solutions of correct strength.

(a) Preliminary neutralization. In the neutralization of the sample of milk, excess of alkali must be avoided, which can be controlled by the use of a properly prepared color-standard.

(b) Conditions of precipitation. Before precipitating with acid, have the dilute, neutralized milk at a temperature between 65° and 75° F. Add enough acid to cause the casein to separate promptly in large flakes, leaving the supernatant liquid clear. Shake the mixture vigorously at intervals during the addition of acid; also after complete precipitation and again after dilution to the 200 cc. mark.

(c) Filtration. Allow most of the liquid to run through the filter before making the final titration with alkali.

(d) Titration with alkali. In titration the filtrate with alkali, avoid an excess of alkali. Add the alkali solution cautiously until, after thorough agitation, a faint but distinct pink color remains through the solution half a minute or longer. The same uniform shade and duration of pink color should be obtained as nearly as possible in all cases.

(e) Acid milk. Milk that is sour or that coagulates on heating should not be used.

(f) Use of preservatives. Milk treated, when fresh, with a small amount of powdered mercuric chlorid and then kept in a cool place gives good results for two or three weeks.

DATA ILLUSTRATING RESULTS OF USE OF METHOD.

We present below some of the data obtained which will serve to give a general idea of the results obtained by our volumetric method in determining the percentage of casein in cow's milk. For the most part, we have worked with the milk of indivdual cows which were in all stages of the lactation period. We have thus met with more extreme variations and more peculiar conditions than would usually be found in examining herd milk. It is possible that under some unusual conditions which have not come under our observation, it may be found that the method may need some slight modifications in details. But so far as our observations go, varying conditions may be met by adjusting the amount of acid used to the requirements of complete precipitation of casein, which becomes largely a matter of experience.

The data below represent the results obtained by three different workers, one of whom possessed only such training as comes from determining the acidity of milk, cream, etc., and who had received only slight instruction in the use of this method. For comparison, results by the "official" method are also given.

PERCENTAGE OF CASEIN IN MILK AS DETERMINED BY DIFFERENT WORKERS.

No. of sample.	Official method.	Volumetric method.		
		1	2	3
1	3.09	3.00	2.95	3.10
2	3.36	3.40	3.45	3.45
3	3.21	3.30	3.40	3.30
4	3.16	3.20	3.20	3.10
5	2.95	2.90	2.90	2.80
6	3.11	3.05	3.10	3.15
7	2.66	3.00	3.00	3.05
8	3.34	3.20	3.00	3.10
9	3.62	3.55	3.60	3.55
10	3.20	3.30	3.20	3.10
11	3.22	3.20	3.00	3.10
12	2.68	2.85	2.75	2.80
13	2.92	3.00	2.90	2.90
14	2.79	2.85	2.80	2.95
15	2.84	2.85	2.80	2.70

Results of different workers are usually within 0.2 per ct. of the official method. Variations greater than this have been found to be due to failure to observe with proper care the various precautions indicated.

The method was placed in the hands of the dairy students of the College of Agriculture of Cornell University during the winter of 1908–9 for the purpose of ascertaining whether uniform results could be obtained by different individuals. Satisfactory results were reported. Dr. Redfield, also of Cornell University, reports that the method gives excellent results in his hands.

The following table contains data illustrating the results of casein determinations made in fresh milks and after 3 and 7 days in the same milk containing mercuric chlorid.

PERCENTAGES OF CASEIN IN MILK TREATED WITH MERCURIC CHLORID.

Official method.	Volumetric method.		
Fresh milk.	Fresh milk.	At 3 days.	At 7 days.
2.47	2.55	2.50	2.50
2.60	2.70	2.65	2.55
2.64	2.60	2.65	2.70
2.78	2.80	2.70	2.75
2.81	2.90	2.90	2.80
2.81	2.85	2.70	2.75
2.87	2.90	2.90	2.85
3.00	3.00	3.00	3.05
3.00	3.00	3.00	3.00
3.03	3.05	3.05	3.05
3.04	3.00	3.00	3.00
3.12	3.05	3.05	3.00
3.13	3.15	3.15	3.15
3.16	3.10	3.10	3.10
3.18	3.20	3.10	3 10
3.29	3.30	3.30	3.30
3.43	3.30	3.35	3.50
3.59	3.60	3.50	3.55
3.78	3.80	3.60	3 70
3.86	3.80	3.80	3.70
4.04	4.20	4.20	4.20

USE OF OTHER ACIDS AND ALKALIS.

Other alkalis (hydroxids of barium and calcium) and other acids (hydrochloric and sulphuric) were employed in developing the test but were not found to give satisfactory results. In the Matthaiopoulos method, sulphuric acid is used. The special advantage of dilute acetic acid, as compared with the other acids tried, lies in its smaller dissolving and absorbing properties for casein.[9]

MODIFICATIONS FOR USE OF CHEMISTS.

Instead of using 17.5 cc. (18 grams) of milk, and the special strength of solutions indicated, it may be found more convenient in chemical laboratories to use 20 cc. of milk and tenth-normal solutions of acid and alkali. In such cases, the method is carried out in the usual manner and the percentage of casein calculated by the following formula.

$$\frac{A}{2} - B \times 1.0964 = \text{per ct. of casein.}$$

By using 22 cc. of milk and tenth-normal acid and alkali, the formula becomes

$$\frac{A}{2} - B = \text{per ct. of casein.}$$

Each cubic centimeter of standard solution corresponds to one per ct. of casein in milk under these conditions.

USES OF CASEIN TEST.

A simple method for determining casein in milk can be utilized to advantage under a variety of conditions, and we will briefly consider some of the principal opportunities for its application.

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[9] N. Y. Agr. Expt. Sta., Tech. Bul. No. 3.

(1) *In dairy schools.*—As a matter of general educational training in making a laboratory study of the composition of milk, a casein test has value, independent of its possible practical applications.

(2) *In dairy nutrition investigations.*— In many dairy investigations of nutrition problems, it is desirable to know the percentage of casein in milk. This factor has frequently been omitted on account of the amount of work involved in determining casein by the "official" method.

(3) *In studies of composition of milk.*— In chemical laboratories, especially those connected with agricultural experiment stations, where systematic studies of the composition of milk are being made, the determination of casein is usually a necessity, if results of value are sought.

(4) *In municipal and state inspection laboratories.*— The inspection of milk by municipal and state authorities has rarely taken casein into consideration in determining the normal character of milk. The relation of fat and casein can be made a desirable basis for ascertaining when fat has been removed from, or skim-milk added to, normal milk.

(5) *In the preparation of modified milk for infant feeding.*— It is a common practice among physicians to modify cow's milk on the basis of the relation of fat to casein for feeding infants. The general purpose is diminution of the ratio of casein to fat as it ordinarily exists in cow's milk. The preparation of modified cow's milk for such purposes has usually been based on guess-work. The ability to determine easily the amount of casein, as well as fat, in cow's milk gives physicians a control of the process which they have not previously had.

(6) *In cheese-factories.*— The relation of casein and fat in milk is an important one in connection with cheese-making. There are times when the normal ratio is so disturbed as to call for modifications of the process of cheese-making or else serious loss of cheese yield is apt to be experienced. Thus, in times of severe drought, the casein usually decreases in relation to fat to such an extent as to result in large losses of fat, when the usual conditions of cheese-making are followed.

Such losses may be prevented by proper modification of the conditions of cheese-making. If a cheese-maker at such times were to determine the amount of casein and fat, he would then know the cause of the difficulties and also the remedy. In the case of cheese-makers who have had the advantage of a dairy-school training, much interest and value could be added to the work of cheese-making by determining the percentage of casein in the mixed milk daily or weekly through the season.

Statements have for some time appeared at intervals in the agricultural press to the effect that the determination of casein in milk " bears the same relation to the cheese industry that the determination of the fat content by the Babcock test does to butter-making " and will do " for cheese men what the Babcock test did for buttermakers." Such statements are decidedly misleading, being based on a crude and superficial understanding of the relation of fat and casein to the yield and quality of cheese, a question which is fully discussed in Bulletin No. 308 of this Station.

A CHEMICAL STUDY OF THE LIME-SULPHUR WASH.*

L. L. VAN SLYKE, C. C. HEDGES AND A. W. BOSWORTH.

SUMMARY.

1. **Object.**— The work described in this bulletin was undertaken for the purposes of learning (1) how the composition of the lime-sulphur wash is influenced by conditions of preparation and (2) what the composition is of various commercial preparations.

2. **Chemistry of lime-sulphur wash.**—When sulphur and lime are boiled together in water, calcium and sulphur combine, usually forming one or two compounds, calcium pentasulphide (CaS_5) and calcium tetrasulphide (CaS_4); at the same time another compound is formed, known as calcium thiosulphate (CaS_2O_3), which on boiling changes into calcium sulphite ($CaSO_3$) and free sulphur. Calcium sulphite on exposure to air changes into calcium sulphate ($CaSO_4$).

3. **Experiments with different formulas.**— Preparations were made containing 125 pounds of sulphur with 52, 60 and 65 pounds, respectively, of pure lime. The general results are summarized as follows:

(a) The specific gravity or density of the preparation and the amount of sulphur and calcium in solution increased with the amount of lime used.

(b) When the largest amount of lime was used, the compound present was mostly calcium tetrasulphide (CaS_4); when the smallest amount of lime was used, the mixture was more nearly pentasulphide (CaS_5).

(c) In the undissolved portion or sediment, free sulphur was present in largest amounts when the smallest amout of lime

* A reprint of Bulletin No. 319.

was used, and the amount decreased when larger amounts of lime were used. Calcium sulphite was present in smallest amounts when the least amount of lime was used.

4. Experiments in boiling mixture different lengths of time. — Different mixtures were boiled 45, 60 and 90 minutes, with the following results:

(a) The largest amount of soluble sulphides was formed by boiling about one hour, especially when the largest amount of lime was used.

(b) In general, increased length of boiling decreases the amount of thiosulphate and increases the amount of sulphite.

(c) The amount of sediment increases with length of boiling, owing to increased formation of calcium sulphite, etc. The amount of free sulphur in sediment decreases with length of boiling.

5. Home-made preparations.— Examination was made of concentrated home-made mixtures and of dilute mixtures prepared according to the formula, 15 pounds of sulphur and 20 pounds of commercial lime. The results were not as satisfactory as in case of the other preparations already described, probably due to use of impure lime. In the case of the 15-to-20 formula, the sulphide compounds of calcium appear to be decomposed forming compounds containing much less sulphur than the tetrasulphide (CaS_4).

6. Effect of adding lime to diluted lime-sulphur solution.— A concentrated solution was diluted to 50 gallons, using 8 gallons of water for 1 gallon of concentrate, and 10 pounds of lime then added. The amount of sulphide sulphur was decreased, while thiosulphate was increased with formation of free sulphur. The higher sulphides of calcium were decomposed, forming compounds containing less sulphur. The changes thus caused may be so great as to seriously decrease the insecticidal power of the mixture.

7. Use of sediments in making lime-sulphur wash.— When nearly pure lime is used, the sediment consists largely of calcium sulphite ($CaSO_3$), free sulphur, hydroxide and car-

bonate of lime, and can be added to fresh amounts of sulphur and lime in making additional wash. This should not be done when the lime used contains magnesium compounds.

8. Effect of using magnesium oxide in place of lime in making lime-sulphur wash.— Magnesium oxide does not form sulphides when boiled with sulphur. Some limited action takes place which results in producing hydrogen sulphide gas. When magnesium oxide is present in lime, it tends to decompose and decrease the amount of sulphides of calcium found. Hydrogen sulphide gas thus produced is poisonous and may affect unfavorably the person who handles the mixture during boiling.

9. Commercial lime-sulphur preparations.— Several samples of each of four different brands of solutions were examined. One brand contained varying amounts of sediment, one sample nearly 20 per ct. The percentage of soluble sulphides was found to vary from 16.5 to 25.6 per ct.; in most cases the percentage was between 23 and 24. The sulphide compounds present were tetrasulphide (CaS_4) and pentasulphide (CaS_5), the proportions varying somewhat; on an average, the two compounds were present in approximately equal proportions.

One sample of a dry powder was examined, the result showing that at the price charged the cost is higher than in case of the commercial solutions.

INTRODUCTION.

The chemical investigation of the so-called lime-sulphur wash, the results of which are given in this bulletin, was undertaken in response to numerous inquiries that were coming to the Station in increasing number. Many of the questions called for chemical knowledge and there were frequent consultations between the Entomologist and the Chemist of the Station. At the request of the former, it was decided to undertake a study of some of the fundamental points connected with the chemistry of the lime-sulphur wash. To meet the conditions, the investigation has been directed along two general lines: (1) A study of the details of the operation of making the lime-sulphur mixture, and of the composition as influenced by conditions of preparation; (2) a chemical examination of the commercial preparations that have been extensively purchased by fruit-growers.

In connection with the first point, it may be stated that many who had been preparing the mixture at home failed to secure a uniform product at all times, and, consequently, the results of the applications varied greatly at different times. In consequence of this lack of reliable uniformity, many became discouraged and lost all confidence in home-made preparations, especially the concentrated forms. They were then in a frame of mind to make use of commercial preparations. These had not been used long before questions began to be raised about the efficiency of one brand as compared with another. For example, some preparations were clear, free from sediment and retained this condition a long time; some were full of an olive-green, muddy-looking sediment and some, on standing, became filled more or less in time with crystalline deposits containing much sulphur, weakening to that extent the solution of sulphur compounds. These differences could not fail to attract attention. The manufacturers of the brands that contained much sediment claimed, without proof, that this muddy, solid matter really added to the effectiveness of the mixture as a scalecide, while the contrary claims were made by manufac-

turers whose mixtures were free from sediment. Under the circumstances, the fruit-growers were greatly confused and came for help to the Entomologist of the Station. In this way the general problems for investigation became definite.

The specific points studied are the following: (1) The liquid portion of lime-sulphur preparations, (2) the sediment, (3) the influence of purity of lime on the composition and yield, (4) the influence of magnesium oxide in lime on the results of the preparation, (5) the influence exerted by length of time and temperature of heating, (6) effect of adding lime and magnesium oxide to diluted mixtures.

The results of the most extensive and careful chemical investigations previously carried on in this field are presented by Haywood in Bulletin 101, U. S. Dept. Agr., Bureau of Chemistry (1907), and by Thatcher in Bulletin 76 of the Washington Station.

CHEMISTRY OF THE LIME-SULPHUR PREPARATION.

Before taking up the details of the results of our investigation, it is desirable to present a brief consideration of certain chemical facts to serve as a foundation for the discussion of the results. In connection with this preliminary treatment, we shall to some extent anticipate some of our results for the sake of illustrating certain statements.

COMPOUNDS OF CALCIUM AND SULPHUR.

Calcium is known to form several different compounds with sulphur. When a mixture of lime (calcium oxide, CaO) or of freshly slaked lime (calcium hydroxide, CaO_2H_2) and sulphur are suspended in water and heated, chemical combination takes place; the calcium of the lime combines with the sulphur. One peculiarity of the combination of calcium and sulphur is that a definite amount of calcium can combine with varying amounts of sulphur to form the several different compounds known. The numerical combining relations of calcium and sulphur are such that 5 parts by weight of calcium (equivalent to 7 parts of pure calcium oxide) combine with 4 parts of sulphur or

some multiple of 4, as 8, 12, 16, 20, etc. Just how many of these compounds may actually be formed, we do not know. Theoretically, it is possible to have, at least, the following compounds of calcium and sulphur:

CALCIUM SULPHIDES.

	Parts of calcium (Ca) by weight.	Parts of sulphur (S) by weight.	Parts of S for one part of Ca.	Chemical formula	Name.
			Ca : S		
1	5	4	1 : 0.8	CaS	Calcium mono-sulphide
2	5	8	1 : 1.6	CaS_2	" di- "
3	5	12	1 : 2.4	CaS_3	" tri- "
4	5	16	1 : 3.2	CaS_4	" tetra- "
5	5	20	1 : 4.0	CaS_5	" penta- "

It will be noticed that the names indicate the relative amounts of sulphur in combination. The general name, *polysulphides* of calcium, is often applied to the members of this series above the first. Most of these compounds can be made, but not all are of practical interest in connection with the lime-sulphur preparation.

When lime and sulphur are boiled together in water, some of the compounds mentioned above are formed; the kinds and amounts of the compounds thus prepared depend chiefly upon the proportions of lime and sulphur, fineness of division, length of time the mixture is boiled, etc. The compounds which appear to be present in largest amounts in the freshly prepared concentrated wash are the fourth (CaS_4) and fifth (CaS_5). These are easily soluble in water, producing an orange-red liquid. According to the explanation most generally accepted, it is believed that these are the compounds which are most efficient in killing scale-insects and that probably the one higher in sulphur (CaS_5) is more effective that the the lower (CaS_4), though it is not yet clearly established in just what manner the insecticidal action takes place nor to what specific compound or compounds it is due.

The simplest compound of calcium and sulphur (CaS), the monosulphide, is a grayish-white solid and is not easily soluble

in water. It probably does not appear at all in the operation of making the lime-sulphur wash, because it decomposes easily in boiling water, and would, therefore, if formed at all, be changed quickly into some other compound.

The higher sulphides of calcium, especially the pentasulphide (CaS_5), are most conveniently formed when lime (calcium oxide, CaO) and water, or calcium hydroxide (CaO_2H_2), are boiled with an excess of sulphur. By an excess of sulphur is meant more than enough to combine with the calcium of the lime compound; in the case of pure materials sulphur would be in excess when one uses over 100 pounds for about 44 pounds of pure lime (calcium oxide) or 58 parts of pure slaked lime (calcium hydroxide).

When the higher sulphides of calcium (CaS_5) and (CaS_4) are formed in the preparation of the lime sulphur wash, there is also formed at the same time another sulphur compound, which is called calcium thiosulphate (CaS_2O_3); and this latter compound, on boiling, changes into calcium sulphite ($CaSO_3$) and free sulphur. The sulphur thus free is in condition to combine with more calcium. Calcium sulphite slowly changes into calcium sulphate on exposure to air. These two latter compounds, sulphite and sulphate of calcium, are not easily soluble and are therefore found in the sediment or undissolved portion of lime-sulphur preparations. As will be seen later, the most prominent sulphur compound in sediment is calcium sulphite ($CaSO_3$).

It may be stated, in addition, that compounds like calcium pentasulphide (CaS_5) absorb oxygen on exposure to air and slowly change into calcium thiosulphate (CaS_2O_3) and free sulphur. In order to prevent exposure to air and avoid this change, the wash, unless it is to be used soon, should be stored in full barrels, tightly stoppered as soon as prepared.

Briefly reviewing the preceding statements, we have seen that we have to deal with three kinds of sulphur compounds in connection with the lime-sulphur wash: (1) Sulphides of calcium, chiefly pentasulphide (CaS_5) and tetrasulphide (CaS_4); (2)

calcium thiosulphate (CaS_2O_3), formed in the process of making the wash and also after the wash is prepared if exposed to air for some time; and (3) calcium sulphite ($CaSO_3$), formed from thiosulphate by taking up oxygen.

COMPOUNDS OF MAGENESIUM AND SULPHUR.

Since commercial lime frequently contains considerable amounts of magnesium oxide, it is interesting and important to know that magnesium does not easily form compounds with sulphur like those formed by calcium and cannot therefore take the place of calcium. Moreover, magnesium oxide, when boiled with water and sulphur, acts as an undesirable agent in causing an actual waste of sulphur during the operation of preparing the mixture. This is due to the fact that, when magnesium hydroxide is boiled with water and sulphur, it forms what is known as magnesium sulphydrate (MgS_2H_2), which easily decomposes, producing the familiar gas, hydrogen sulphide (H_2S), known also as hydrosulphuric acid and sulphuretted hydrogen, familiar about sulphur-springs on account of its characteristic odor. In the preparation of the lime-sulphur mixture with commercial lime containing considerable amounts of magnesium oxide, it has been noticed that the offensive odor of hydrogen sulphide is very prominent over the boiling mixture in the kettle. In such cases the same odor may be noticed in orchards just sprayed with a lime-sulphur mixture prepared with impure lime containing magnesium oxide. The sulphur thus converted into hydrogen sulphide gas is lost and the preparation contains smaller amounts of the desired higher polysulphides of calcium.

Attention should be called to the fact that hydrogen sulphide gas is poisonous when inhaled. One case of poisoning by inhalation of this gas during preparation of the lime-sulphur mixture has come under our observation. The illness, while not serious or prolonged, was uncomfortable. One of the Station employees who has charge of preparing the lime-sulphur mixture has stated that during the days he is engaged in this work he experiences marked loss of appetite. We believe that

the disturbing effects noticed are the result of inhalation of hydrogen sulphide gas given off during the preparation of the lime-sulphur mixture and that the formation of the gas is due to the use of lime containing magnesium oxide.

It may be stated also that when magnesium oxide is added to a concentrated mixture of calcium pentasulphide (CaS_5), which is usually the chief constituent of the lime-sulphur preparation, hydrogen sulphide gas is formed, resulting in loss of calcium pentasulphide.

METHODS OF ANALYSIS.

For the benefit of those interested in the analytical methods employed in obtaining our results, we give a brief outline. Constituents other than sulphur were determined by the methods in common use. (1) *Total sulphur* in solution is determined by oxidizing to sulphate with alkaline solution of hydrogen peroxide, following in essential details the Avery method (U. S. Dept. Agr., Bureau of Chemistry, Bul. 107, p. 34). The use of bromine as an oxidizing agent was carefully tried but the results were less satisfactory. (2) *Thiosulphate sulphur* in solution is determined by the ammoniacal zinc chloride method. (U. S. Dept. Agr., Bureau of Chemistry, Bul. 101, p. 9.) (3) *Sulphide sulphur* in solution is found by subtracting the amount of thiosulphate sulphur from total soluble sulphur. (4) *Free sulphur*, as in sediment, is determined by extraction with carbon bisulphide in the usual manner. (5) *Sulphite sulphur* is estimated by treatment with excess of standardized iodine solution, titrating excess with standardized solution of sodium thiosulphate.

EXPERIMENTAL WORK.

In the work carried on here, a study has been made of various points connected with the preparation of the lime-sulphur mixture with special reference to the difficulties experienced by fruit-growers in making their own concentrated solutions. Among the questions thus raised, we mention the following: (1) Why do home-made preparations often vary so much in concentration when prepared at different times?

(2) What proportions of sulphur and lime and water give the largest amount of soluble sulphur in the form of sulphides of calcium? (3) How is the amount of soluble sulphide sulphur influenced by heating the mixture under different conditions, such as length of time, degree of temperature, etc.? (4) Why is it that home-made preparations contain less sulphur in solution than the best commercial preparations? (5) Does the purity of the lime used affect the amount of soluble sulphide sulphur? (6) When a concentrated solution is diluted and mixed with lime, is the amount of soluble sulphide sulphur affected? (7) Can the undissolved portion remaining after making the lime-sulphur mixture be used again?

In presenting the results of our investigation, we shall consider, in most cases, the following points: (1) Specific gravity or density (including degrees Beaumé). (2) Amount of solution and of sediment. (3) Color of solution and of sediment. (4) Composition of solution in respect to calcium and different forms of sulphur compounds. (5) Composition of sediment in respect to calcium, magnesium and different forms of sulphur.

EXPERIMENTS WITH DIFFERENT FORMULAS.

After some preliminary experiments, it was decided to use varying amounts of lime for a given amount of sulphur. The special object was to ascertain what proportions of lime and sulphur, other conditions being the same, would give the largest amount of calcium sulphides in solution and especially the largest amount of calcium pentasulphide (CaS_5). These experiments were performed in the laboratory on a comparatively small scale; but large quantities were made later to test the results of the laboratory experiments and these experiments on a large scale will be described by the Station Entomologist in another bulletin.

The following proportions of lime and sulphur were used: (1) Sulphur, 125 pounds, lime, 52 pounds; (2) sulphur, 125 pounds, lime, 60 pounds; (3) sulphur, 125 pounds, lime, 65 pounds.

In the laboratory experiments pure lime (calcium oxide) was used. The amount of lime theoretically required to combine with 125 pounds of sulphur to form calcium pentasulphide (CaS_5) in largest amounts is about 60 pounds. It is seen, then, that in the first formula, the lime was not sufficient in amount to combine with all the sulphur. In the second formula the proportions are about those called for by theoretical considerations, while the third formula represents proportions that give more lime than is needed to form calcium pentasulphide.

The mixtures were made up to the equivalent of 50 gallons by the addition of water. At the same time, experiments were made in the case of each formula to ascertain the effects of boiling the mixture for varying periods of time, 45, 60 and 90 minutes. In order to avoid too great duplication of tabulated data, we give all the results together, discussing them separately as far as practicable. In comparing the results in the following tables, one must, of course, take into consideration the length of boiling and, in studying the different formulas, compare the results of experiments in which the boiling was carried on for the same length of time. This is facilitated by the manner in which the experiments are numbered.

(1) *General character of preparations made.* Below we give in tabulated form under each of the formulas used (1) the specific gravity and degrees Beaumé of the mixtures with and without the sediment or undissolved material and (2) the amounts of solution and sediment.

In this connection, we will call attention to the observed color of the solution and sediment. The clear solutions were much alike in color, appearing orange-red or reddish-yellow when seen in a quart fruit jar; when seen in deeper layers, the color appears a deep claret. The color of the sediment was practically the same in all cases. As seen in the mixture, the sediment appears olive-green; but when removed, washed and dried, it appears white or grayish white. When a sample of the dried white sediment is again mixed with some of the clear solution, it soon acquires an olive-green color. Therefore, the color of the sediment, as seen in the lime-sulphur mixture, is due to the combined color of solution and solid.

TABLE I.— SPECIFIC GRAVITY OF MIXTURES; AMOUNT OF SOLUTION AND SEDIMENT.

No. of experiment.	Formula. Sulphur.	Formula. Lime	Duration of boiling of mixture.	Specific gravity of solution. With sediment.	Specific gravity of solution. Without sediment.	Degrees Beaumé of solution. With-sediment.	Degrees Beaumé of solution. Without sediment.	Weight of solution in 50. gallons.	Weight of sediment in 50. gallons.
	Lbs.	Lbs.	Minutes					Lbs.	Lbs.
1-a	125	52	45	1.283	1.2648	32.0	30.4	518.4	16.6
1-b	"	"	60	1.276	1.2500	31.4	29.0	512.0	20.0
1-c	"	"	90	1.264	1.2209	30.3	26.3	491.0	36.0
2-a	125	60	45	1.290	1.2577	32.6	29.8	513.0	25.0
2-b	"	"	60	1.282	1.2441	31.9	28.5	509.0	26.0
2-c	"	"	90	1.297	1.2449	33.2	28.5	504.0	37.0
3-a	125	65	45	1.311	1.2860	34.4	32.2	527.0	20.5
3-b	"	"	60	1.322	1.2740	35.3	31.2	519.3	31.0
3-c	"	"	90	1.323	1.2708	35.4	30.9	509.0	42.5

The data indicate that the specific gravity in the mixture of solution and sediment increased with the increased amount of lime used. In the clear solution, the tendency of the specific gravity is to increase with increased amounts of lime, indicating a greater concentration of solution as noticed later.

(2) *Composition of solution.*—In the table following, we give the percentages of the important constituents of the clear solution. The percentage of calcium in combination with sulphides is calculated by subtracting from the total amount of calcium in solution the amount of calcium in combination as thiosulphate.

TABLE II.—PERCENTAGES OF CONSTITUENTS IN SOLUTION.

No. of experiment.	Formula. Sulphur.	Formula. Lime.	Sulphur. Total.	Sulphur. In form of sulphides.	Sulphur. In form of thiosulphates.	Calcium in combination as sulphides.	Ratio of calcium to sulphide sulphur.
	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	Per ct.	Ca : S
1-a.......	125	52	21.17	17.25	3.92	4.45	1 : 3.87
1-b.......	"	"	19.90	16.40	3.50	5.17	1 : 3.17
1-c.......	"	"	20.72	18.95	1.77	4.78	1 : 3.96
2-a.......	125	60	22.35	19.56	2.79	5.31	1 : 3.68
2-b.......	"	"	22.39	20.64	1.75	5.35	1 : 3.86
2-c.......	"	"	22.37	20.83	1.54	6.12	1 : 3.40
3-a.......	125	65	21.83	17.73	4.10	5.58	1 : 3.18
3-b.......	"	"	23.72	22.03	1.69	7.04	1 : 3.13
3-c.......	"	"	23.55	22.25	1.36	6.93	1 : 3.21

In studying the data embodied in Table II, we notice the following points of interest:

(1) The total amount of sulphur in solution, as well as the amount of sulphur in sulphide form, tends to increase with the use of increased amounts of lime.

(2) The amount of thiosulphate sulphur shows a tendency to be smaller when larger amounts of lime are used. We shall see later, in studying the composition of the sediment, that more sulphite sulphur is usually formed when increased amounts of lime are used. This indicates that more or less thiosulphate sulphur has been changed into sulphite sulphur and that in reality more thiosulphate has been formed than is indicated by the figures given in Table II.

(3) The amount of calcium in combination in the form of soluble sulphides increases when the proportion of lime used increases.

(4) The amount of sulphur for one part of calcium is least when the largest proportion of lime is used. Referring to the statements made on page 357, we have noticed that when a sulphide of calcium is pure pentasulphide (CaS_5), it contains four parts by weight of sulphur for one of calcium. When the ratio is lower, there is less calcium pentasulphide and more tetrasulphide (CaS_4) and in some cases there is probably an admixture of soluble sulphides containing still less sulphur (CaS_3, CaS_2). Of course, the increase of calcium in solution may be accounted for to a small extent by the presence of calcium hydroxide (CaO_2H_2), which is present when an excess of lime is used. If the solubility of calcium hydroxide is no greater in the lime-sulphur wash than in water, the amount is practically negligible for our purposes. Referring to the last column in Table II, it is seen that when the smallest amount (52 pounds) of lime is used, the ratio of calcium to sulphur indicates in two experiments (1-a and 1-c) a calcium sulphide corresponding very closely in composition to the pentasulphide (CaS_5). In experiment 1-b, the ratio is about that required for the tetrasulphide (CaS_4). Why the results of this experiment differ so markedly from the other two, we are not able

to state. In the case of experiments 2-a, 2-b, 2-c, when we used 60 pounds of lime, the calcium sulphide appears to be largely pentasulphide in two cases and a mixture in the other, with the tetrasulphide predominating. When the largest amount (65 pounds) of lime was used, the tetrasulphide appears to be the only form present, so far as the ratio indicates anything, since we have about 3.2 parts of sulphur for one of calcium. In this case, it is noticeable, as already stated, that we have the largest amount of sulphide sulphur in solution. From these results, it appears, according to our interpretation, that a considerable excess of lime gives a larger yield of soluble sulphide sulphur but that this is largely or wholly tetrasulphide (CaS_4); in other words, the increased yield of sulphide appears to be at the expense of the pentasulphide (CaS_5), which is supposed to be more efficient as a scalecide than the tetrasulphide.

(3) *Composition of sediment.*— The more important constituents of the sediment in these experiments are the different forms of sulphur and the calcium. In the sediment or undissolved portion, we find uncombined or free sulphur, and sulphur combined in the forms of calcium sulphite ($CaSO_3$) and calcium sulphate ($CaSO_4$). The various percentages are tabulated below. The specific gravity of the sediment varied considerably according to composition; it averaged about 2.5, one gallon weighing about 20 pounds.

TABLE III.— PERCENTAGE OF CONSTITUENTS IN SEDIMENTS.

No. of experiment.	Formula		Sulphur.			Calcium	Calcium oxide (CaO) equivalent to calcium.
	Sulphur.	Lime.	Uncombined or free.	In form of sulphite.	In form of sulphate.		
	Lbs.	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1-a.......	125	52	77.31	2.77	0.02	12.63	17.68
1-b.......	"	"	60.32	4.43	0.93	13.71	19.20
1-c.......	"	"	23.94	17.35	0.16	27.54	38.56
2-a.......	125	60	9.07	20.18	0.11	31.89	44.64
2-b.......	"	"	3.32	22.66	0.03	32.86	46.00
2-c.......	"	"	8.61	21.33	0.06	31.63	44.28
3-a.......	125	65	30.12	3.31	1.37	34.20	47.88
3-b.......	"	"	0.24	22.80	0.15	31.67	44.34
3-c.......	"	"	0.43	23.17	0.62	35.25	9.35

The data in the preceding table suggest (1) that when the smallest amount of lime is used, the sediment consists more largely of uncombined sulphur; (2) that the amount of sulphite sulphur tends to increase with the amount of lime used; (3) that the amount of sulphate sulphur is usually insignificant.

(4) *Relative efficiency of different formulas.*— By efficiency in this connection we mean the strength of a lime-sulphur wash in respect to the calcium pentasulphide (CaS_5) present. This definition is based on the hypothesis that calcium pentasulphide is the most effective compound in the solution for killing scale-insects. On this hypothesis therefore, it is desirable to have in the lime-sulphur preparation the largest possible amount of this compound. A consideration of the composition of the solution and sediment does not by itself serve fully to give us a complete idea of the relative efficiency of the different formulas used in preparing the lime-sulphur mixture. This can be definitely brought out only by ascertaining the amount of sulphur in different forms and of lime appearing in the solution and sediment, as compared with the amount of the two constituents used. For example, we used in every case 125 pounds of sulphur; now, it is desirable to know what became of this amount,— how much went into solution in different forms and how much went into the sediment either as unchanged sulphur or in combination. It is instructive to follow in a similar manner also the distribution of the lime in the solution and in the sediment or undissolved portion. Results are presented in the following table in such a way as to enable us to gain this information approximately. If our results were absolutely accurate, we should be able to show that the amount of lime and of sulphur in the dissolved and undissolved portions are just equal to the amounts used; but owing to the difficulty of taking strictly accurate samples of the suspended materials and to imperfect methods of analysis, some discrepancies inevitably appear, though not sufficiently serious to impair the value of the results obtained.

An examination of Table IV below suggests the following summarized statements: (1) The amount of sulphide sulphur in solution increases generally when the amount of lime used increases. (2) The use of increased amounts of lime appears to result generally in the production of smaller amounts of thiosulphate sulphur but somewhat larger amounts of sulphite sulphur, as already pointed out (p. 364). (3) The amount of lime in solution is notably increased by use of larger amounts of lime. (4) The amount of sediment is usually somewhat greater when larger amounts of lime are used. (5) The amount of free sulphur in sediment is notably less when larger amounts of lime are used. (6) The amount of lime in sediment is usually greater when increased amounts of lime are used.

TABLE IV.— AMOUNTS OF SULPHUR AND OF LIME IN SOLUTION AND IN SEDIMENT.

No. of experiment.	Formula.		In solution (from 50 gals. of mixture).					In sediment.			
	Sulphur.	Lime.	Total wt.	Sulphur as sulphides.	Sulphur as thiosulphate.	Lime in sulphides.	Total lime.	Total wt.	Free sulphur.	Combined sulphur (sulphite and sulphate)	Lime.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1–a	125	52	518.4	89.4	20.3	33.0	50.1	16.6	12.8	0.5	2.9
1–b	"	"	512.0	84.0	17.9	37.1	52.7	20.0	12.1	1.1	3.8
1–c	"	"	491.0	93.0	8.7	32.8	40.4	36.0	8.6	6.3	13.9
2–a	125	60	513.0	100.3	14.3	38.1	50.7	25.0	2.2	5.1	11.1
2–b	"	"	509.0	105.0	9.0	38.1	46.0	26.0	0.9	5.9	12.0
2–c	"	"	504.0	105.0	7.8	43.2	50.0	37.0	3.2	7.9	16.4
3–a	125	65	527.0	93.4	21.6	41.2	60.1	20.0	6.0	1.0	9.5
3–b	"	"	519.3	114.4	5.6	51.2	58.9	31.7	0.1	7.2	14.0
3–c	"	"	509.0	113.3	6.6	49.4	55.2	42.5	0.2	10.1	21.0

The facts can be made still more readily comparable by considering in more detail two particular points: (1) The relative distribution of sulphur as sulphide and thiosulphate and as combined sulphur (sulphite and sulphate) in sediment; (2) the relative amounts of calcium polysulphides (CaS_4 and CaS_5) present in solution. These points we will now consider.

TABLE V.—SHOWING RELATIVE DISTRIBUTION OF SULPHUR COMPOUNDS IN SOLUTION AND SEDIMENT.

No. of experiment.	Formula		Percentage of total sulphur used present in solution.	Percentage of dissolved sulphur in form of sulphides.	Percentage of dissolved sulphur in form of thiosulphate.	Percentage of total sulphur in form of combined sulphur in sediment.
	Sulphur.	Lime.				
	Lbs.	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1-a	125	52	87.8	71.5	16.3	0.4
1-b	"	"	81.5	67.2	14.3	0.9
1-c	"	"	81.4	74.4	7.0	5.0
2-a	125	60	91.7	80.2	11.5	4.0
2-b	"	"	91.2	84.0	7.2	4.7
2-c	"	"	90.2	84.0	6.2	6.1
3-a	125	65	92.0	74.7	17.3	0.8
3-b	"	"	96.0	91.5	4.5	5.8
3-c	"	"	95.9	90.6	5.3	8.1

In the third column, we give the number of pounds of sulphur in solution for every 100 pounds of sulphur used; in the next column, we give the proportion of the 100 pounds of sulphur used which is in solution as sulphide sulphur; and, in the next column, the proportion appearing as thiosulphate sulphur. In the last column, we give the proportion of the total sulphur used which appears in the sediment as combined sulphur (sulphite and sulphate). To illustrate, we find in experiment 1-a that, for 100 pounds of sulphur used, 87.8 pounds go into solution; this amount being made up of 71.5 pounds of sulphide sulphur and 16.3 pounds of thiosulphate sulphur; while the amount of combined sulphur present in the sediment is 0.4 pound.

We find, in general, that with the use of increased amounts of lime, larger proportions of the sulphur used go into solution and apparently smaller proportions of thiosulphate sulphur. As presented in Tables IV and V the data indicates, in general, that when the amount of thiosulphate sulphur decreases in the solution, the amount of sulphite sulphur in the sediment increases. Unless this fact is considered, the natural inference in examining the data is that when greater amounts of lime are used, smaller amounts of thiosulphate sulphur are formed, and that, therefore, just so much more sulphur ap-

pears or should appear as sulphides. While less thiosulphate appears with the use of larger amounts of lime, the difference is really less than appears, because some of the thiosulphate changes into sulphite sulphur and appears in the sediment as insoluble calcium sulphite and sulphate. It is noticeable that the combined sulphur in the sediment increases usually when thiosulphate decreases, though the amounts changed are not equivalent, owing probably to imperfections in methods of analysis. This change of thiosulphate into sulphite sulphur takes place easily and attention has already been called to it (p. 364).

Taking up the second point mentioned above, viz., the amounts of higher sulphides (CaS_5 and CaS_4) present in solution, we have seen that, in the compound containing more sulphur (CaS_5), we have 4 parts by weight of sulphur for one part of calcium; and, in the compound containing less sulphur (CaS_4), we have 3.2 parts of sulphur for one of calcium. If we assume one or both of these two compounds to be the only sulphides of calcium present in solution, we can calculate the respective amounts of each. This has been done and the results are presented in the table following.

TABLE VI.—PROPORTIONS OF CALCIUM PENTASULPHIDE (CaS_5) AND TETRASULPHIDE (CaS_4) IN SOLUTION.

No. of experiment.	Formula.		Ratio of calcium to sulphur.	Percentage of sulphur in solution present as tetra-sulphide (CaS_4).	Percentage of sulphur in solution present as penta-sulphide (CaS_5).	Amount of tetra-sulphide (CaS_4) in 50 gallons of solution.	Amount of penta-sulphide (CaS_5) in 50 gallons of solution.
	Sulphur.	Lime.					
	Lbs.	*Lbs.*	*Ca : S*	*Per ct.*	*Per ct.*	*Lbs.*	*Lbs.*
1-a	125	52	1 : 3.87	16.7	83.3	15.0	89.4
1-b	"	"	1 : 3.17	100.0	00.0	84.0	00.0
1-c	"	"	1 : 3.96	5.3	94.7	4.9	88.1
2-a	125	60	1 : 3.68	40.0	60.0	40.1	60.2
2-b	"	"	1 : 3.86	16.7	83.3	17.5	87.5
2-c	"	"	1 : 3.40	75.0	25.0	78.8	26.2
3-a	125	65	1 : 3.18	100.0	00.0	93.4	00.0
3-b	"	"	1 : 3.13	100.0	00.0	114.4	00.0
3-c	"	"	1 : 3.21	100.0	00.0	113.3	00.0

On the basis of the data presented in this table, it is seen that the largest amount of the higher sulphide (CaS_5) is produced when the least amount of lime is used or, stated another way, when the sulphur is in excess compared with the lime. When the largest amount of lime is used, the sulphide appears to be entirely in the form of calcium tetrasulphide (CaS_4). While the largest yield of sulphide sulphur comes with the use of the largest amount of lime, the compound formed is apparently all tetrasulphide; and when the least amount of lime is used, less sulphide is formed but a larger proportion of it is pentasulphide. As previously stated, it is at present supposed that the pentasulphide has more powerful insecticidal properties than the tetrasulphide, though we must regard this view as a supposition and not as yet experimentally established.

EXPERIMENTS IN BOILING LIME-SULPHUR MIXTURE FOR DIFFERENT LENGTHS OF TIME.

The effect of heating lime-sulphur mixtures was tested with the three different formulas previously considered. The special points to be noticed are the amounts and composition of solution and sediment. From the data already presented, we have selected those contained in the following table to cover the points of special importance.

TABLE VII.—EFFECT OF BOILING FOR DIFFERENT LENGTHS OF TIME ON LIME-SULPHUR MIXTURE.

Formula.		Time of boiling.	Solution.					Sediment.			
Sulphur.	Lime.		Wt.	Sulphur as sulphides	Sulphur as thiosulphates.	Lime as sulphide.	Total lime.	Wt.	Free sulphur.	Combined phur (sulphite, etc.).	Lime.
Lbs.	*Lbs.*	*Min.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
125	52	45	518.4	89.4	20.3	33.0	50.1	16.6	12.8	0.5	2.9
"	"	60	512.0	84.0	17.9	37.1	52.7	20.0	12.1	1.1	3.8
"	"	90	491.0	93.0	8.7	32.8	40.4	36.0	8.6	6.3	13.9
125	"	45	513.0	100.3	14.3	38.1	50.7	25.0	2.2	5.1	11.1
"	"	60	509.0	105.0	9.0	38.1	46.0	26.0	0.9	5.9	12.0
"	"	90	504.0	105.0	7.8	43.2	50.0	37.0	3.2	7.9	16.4
125	"	45	527.0	93.4	21.6	41.2	60.1	20.0	6.0	1.0	9.5
"	"	60	519.3	114.4	5.6	51.2	58.9	31.7	0.1	7.2	14.0
"	"	90	509.0	113.3	6.6	49.4	55.2	42.5	0.2	10.1	21.0

The results embodied in the preceding table are summarized as follows:

(1) *Weight of solution and sediment.*— In every case, increased length of boiling decreases the weight of the completed solution and increases the amount of sediment.

(2) *Sulphur as sulphides.*— In general, boiling the mixture for one hour produces the largest amount of soluble sulphides, especially when larger amounts of lime are used.

(3) *Thiosulphate and sulphite sulphur.*— Increased length of boiling results in the appearance of smaller amounts of thiosulphate in solution. In general, we should expect larger amounts of thiosulphate, due to prolonged exposure at boiling temperature to the action of atmospheric oxygen. Larger amounts of thiosulphate are actually formed but a considerable amount changes into sulphite sulphur and appears in the sediment as calcium sulphite along with some free sulphur. It is necessary to boil the solution long enough to change the thiosulphate first formed into sulphite and free sulphur; the free sulphur thus formed is utilized, being redissolved and converted largely into sulphide sulphur. Boiling for one hour in the presence of sufficient lime appears to be long enough in general to reduce thiosulphate to a relatively small amount and thus utilize the sulphur more largely as sulphide.

(4) *Lime in solution.*— The amount of lime in solution appears usually to decrease with length of boiling, due to change of calcium thiosulphate into insoluble calcium sulphite.

(5) *Free sulphur in sediment.*— In general, the amount of free sulphur in sediment is greatest when the boiling of the mixture is shortest. This is due, as would be expected, to incomplete action of lime on sulphur and is noticeably greater when the amount of lime used is least.

(6) *Combined sulphur in sediment.*— The sulphur in sediment, combined largely as calcium sulphite (CaS_3), with small amounts of sulphate (CaS_4), increases with the length of boiling. As already pointed out, this comes largely or wholly from the change of calcium thiosulphate (CaS_2O_3) into calcium sulphite and free sulphur.

(7) *Lime in sediment.*— The amount of lime in sediment increases with the time of boiling; this naturally accompanies the formation of calcium sulphite, which, being insoluble, appears as a part of the sediment and usually as a very large part of it.

ANALYSIS OF HOME-MADE PREPARATIONS.

In order to ascertain the composition of some lime-sulphur washes which had been prepared under the direction of the Station Entomologist and used in regular work, analysis was made of preparations made according to two formulas. We may regard these as representing home-made preparations of a good type.

Samples 13, 14 and 15 represent concentrated preparations made with 125 pounds of sulphur, 65 pounds of commercial lime (containing 79.4 per ct., equal to about 52 pounds, of calcium oxide), and enough water added to make 50 gallons of completed mixture. In spraying, this solution is diluted with 8 or 9 parts of water. Samples 16, 17 and 18 represent preparations made by the old standard formula, 15 pounds of sulphur, 20 pounds of commercial lime (containing about 16 pounds of calcium oxide), and enough water to make 50 gallons of mixture; this kind of mixture is used in spraying without further dilution and without removal of sediment. Preparations 13–15 contained small amounts of sediment, since the solution was drawn from the kettle into barrels after the coarse portion of the sediment was allowed to settle and while there was more or less fine matter still in suspension.

(1) *General character of home-made preparations.*— The filtered solution was reddish-golden in case of the concentrated preparations and golden-yellow in case of the dilute. The sediment, as seen in the mixture, was olive-green in color in the concentrated preparations and light-yellow in the dilute. The degrees Beaumé in the concentrated mixtures (13–15) varied from 25.2 to 29.2.

(2) *Composition of home-made preparations.*— The data under this head will be presented in two tables, giving (1st)

the percentage composition and (2nd) the composition by pounds in 50 gallons of mixture. The figures given are for the mixture of solution and sediment.

TABLE VIII.— PERCENTAGE COMPOSITION OF HOME-MADE PREPARATIONS.

No. of preparation.	Formula. Sulphur	Formula. Lime	Sulphur. In form of sulphides.	Sulphur. In form of thiosulphates.	Calcium in combination as sulphides.	Ratio of calcium to sulphide sulphur.
	Lbs.	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	*Ca : S*
13	125	65*	13.1	3.2	4.1	1 : 3.2
14	"	"	12.5	3.2	3.9	1 : 3.2
15	"	"	13.0	2.9	4.1	1 : 3.2
16	15	20†	2.4	1.1	1.4	1 : 1.7
17	"	"	2.3	1.0	1.5	1 : 1.5
18	"	"	1.9	1.4	1.1	1 : 1.7

* Containing about 52 pounds of calcium oxide. † Containing about 16 pounds of calcium oxide.

TABLE IX.— POUNDS OF CONSTITUENTS IN 50 GALLONS OF SOLUTION.

No. of preparation.	Formula Sulphur.	Formula Lime.	Weight of 50 gallons of mixture	Sulphur. Total	Sulphur. In form of sulphides	Sulphur. In form of thiosulphate.	Sulphur. In form of sulphite and sulphate.	Sulphur. Free sulphur	Lime, magnesia, etc. in 50 gallons.	Weight of sediment in 50 gallons.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
13	125	65*	522.0	86.8	68.5	16.5	1.1	0.7	48.0	23.0
14	"	"	514.0	82.9	64.3	16.2	0.2	2.2	46.0	20.0
15	"	"	505.5	82.0	65.8	14.7	0.2	1.3	43.2	5.5
16	15	20†	443.5	15.9	10.4	4.8	—	—	18.7	13.5
17	"	"	443.0	15.5	10.2	4.6	—	—	19.0	13.5
18	"	"	443.0	15.8	8.6	6.4	—	—	18.8	13.5

* Containing about 52 pounds of calcium oxide. † Containing about 16 pounds of calcium oxide.

The questions of special interest in connection with the preparations under discussion are the following: (1) How does the amount of sulphides produced in relation to the amount of sulphur used compare with the same relations in experiments 1–a, 1–b, etc.? (2) What is the relative efficiency in respect to sulphides produced in preparations 13–15 as compared with preparations 16–18? We can obtain assistance in answering these questions by arranging our data in the following manner:

TABLE X.—PERCENTAGE OF SULPHUR USED CONVERTED INTO SOLUBLE SULPHIDES.

No. of experiments.	Formula Sulphur.	Formula Lime.	Average percentage of sulphur used converted into soluble sulphides.	Ratio of calcium to sulphide sulphur
	Lbs.	*Lbs.*	*Per ct.*	*Ca : S*
1–a—1–b—1–c	125	52	71.0	1 : 3.90
2–a—2–b—2–c	"	60	82.7	1 : 3.75
3–a—3–b—3–c	"	65	85.6	1 : 3.20
13—14—15	"	52	53.0	1 : 3.20
16—17—18	15	16	65.0	1 : 1.65

From a study of the three tables preceding (VIII, IX and X), we notice the following points:

(1) The preparations represented by numbers 13–15 are shown to contain the smallest amount of sulphide sulphur in proportion to the amount of sulphur used in making the mixture. The same proportions of sulphur and lime were used in these experiments as in 1–a–b–c. The difference is due largely to the presence of magnesium oxide in the commercial lime used in preparations 13–15, the lime used in the other work being strictly pure. Experiments 16–18 show less soluble sulphide in proportion to sulphur used than we should expect, due probably to the presence of magnesium oxide in the lime used.

(2) When we compare the results of the various experiments with reference to the ratio of calcium to sulphur, we find that in preparations 13–15 the sulphide appears to be tetrasulphide of calcium (CaS_4). In preparations 16–18, the ratio of sulphur to calcium is abnormally low, indicating the presence of calcium disulphide (CaS_2) for the most part and little or no sulphide containing more sulphur. While this condition can not be authoritatively explained on the basis of any work done by us, it is suggested that in using lime containing magnesium oxide with so large an amount of water, the higher polysulphides (CaS_4 and CaS_5) were decomposed and the disulphide (CaS_2) formed, together with free sulphur.

(3) In comparing preparations 13–15 and 16–18, it must be kept in mind that the former are concentrated and before being

used are diluted by adding 8 gallons of water to one gallon of concentrated mixture, while preparations 16–18 are applied without further dilution. Under these circumstances, it will be seen that the application of sulphide sulphur is considerably greater in the case of mixtures 16–18. This can be conveniently shown as follows:

No. of preparation.	Formula.		Amount of sulphide sulphur in 50 gallons of mixture ready for application.
	Sulphur.	Lime.	
	Lbs.	*Lbs.*	*Lbs.*
13–15	125	52	7.35
16–18	15	16	9.75

These figures indicate that in applying mixture 16–18, about 25 per ct. more sulphide sulphur is used than in case of 13–15.

(4) It is also noticeable that the proportion of thiosulphate sulphur is much greater in preparations 16–18 than in 13–15, when the comparison is based on the mixtures properly diluted for application: Thus, in 50 gallons of mixtures 16–18, we have an average of 5.3 pounds of thiosulphate sulphur; while in, the diluted form, 50 gallons of preparations 13–15 contain about 1.8 pounds of thiosulphate sulphur, or about one-third the amount present in mixtures 16–18.

EFFECT OF ADDING LIME TO DILUTED LIME-SULPHUR SOLUTION.

The practice of diluting a concentrated lime-sulphur solution and adding lime just previous to making application to trees is common. The question has been raised as to what, if any, effect this might have upon the composition of the sulphur compounds in solution, especially the calcium polysulphides. For the purpose of studying this question concentrated lime-sulphur solutions were diluted with water in the proportion of 8 gallons of water to one gallon of concentrated solution, and to 50 gallons of the diluted mixture there were added 10 pounds of commercial lime.

Without giving the detailed analytical data, it will suffice for our purpose to indicate the changes in the form of pounds of constituents in 50 gallons of dilute mixture with and without addition of lime. Four different concentrated solutions of the lime-sulphur wash were diluted and treated in the manner indicated. The solutions used were free from sediment. In the table following, we give the results in such form as to show what changes occurred in the soluble sulphur compounds.

TABLE XI.— EFFECT OF ADDING LIME TO DILUTE LIME-SULPHUR WASH.

No. of experiment.	Condition of mixture.	Total sulphur in mixture.	Sulphur in solution.		Sulphur in sediment.	Percentage of total sulphur.			Ratio of calcium to sulphide sulphur.
			In form of sulphide.	In form of thiosulphate.		In form of sulphide.	In form of thiosulphate.	In form of free sulphur.	
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*				*Ca* : *S*
19–a	Untreated.	13.25	12.72	0.53	0	96.0	4.0	0	1 : 3.58
19–b	Treated...	13.25	11.10	1.90	0.25	83.8	14.3	1.9	1 : 2.50
20–a	Untreated.	14.40	13.70	0.70	0	95.1	4.9	0	1 : 3.51
20–b	Treated...	14.40	8.50	5.40	0.50	59.0	37.5	3.5	1 : 2.16
21–a	Untreated.	13.10	12.55	0.55	0	95.8	4.2	0	1 : 3.65
21–b	Treated...	13.10	8.50	4.30	0.30	64.9	32.8	2.3	1 : 3.00
22–a	Untreated.	13.30	12.40	0.90	0	93.2	6.8	0	1 : 3.64
22–b	Treated...	13.30	9.80	3.20	0.30	73.7	24.0	2.3	1 : 2.10

In Table XI the amounts of sulphur in various compounds is given in pounds for 50 gallons of diluted solution, first without lime and then after addition of lime in each case. The mixtures contained in any given case the same amount of total sulphur, of course, before and after treatment with lime, the amount of sulphur in the different experiments varying from 13.10 to 14.40 pounds in 50 gallons of diluted mixture. There is also given in each case the amount of sulphide sulphur, thiosulphate sulphur and free sulphur, or sulphur in sediment, before and after treatment with lime. We also give the percentage of total sulphur in these three different forms before and after treatment with lime. In the last column, we give the ratio of calcium to sulphide sulphur before and after treatment with lime. To illustrate, we take experiments 19–a and b. In

the mixture before and after treatment, we have 13.25 pounds of total sulphur; of this, we find 12.72 pounds (or 96 per ct.) present in the form of sulphides before addition of lime, while, after treatment with lime, we find only 11.10 pounds (or 83.8 per ct.) present as sulphide. Thus, in this case there was a decrease of 1.62 pounds of sulphide sulphur. In the case of thiosulphate, we have 0.53 pound (or 4 per ct.) of thiosulphate sulphur before treatment with lime; after treatment, we find 1.9 pounds of thiosulphate (or 14.3 per ct.), an increase of 1.37 pounds. The solution before addition of lime contained no free sulphur, but after treatment it contained 0.25 pound or nearly 2 per ct. of all the sulphur present in various forms.

Summarizing the results contained in Table XI, we notice the following points of interest:

(1) The amount of sulphur in the form of sulphides decreased by treatment with lime by quantities varying from 1.63 to 5.15 pounds and averaging 3.35 pounds.

(2) The quantity of thiosulphate sulphur was increased by treatment with lime, the increase varying from 1.37 to 4.65 pounds and averaging 3 pounds.

(3) The amount of free sulphur increased after addition of lime, the increase varying from 0.25 to 0.50 pound and averaging 0.34 pound.

(4) The ratio of calcium to sulphide sulphur was about 1:3.60 before addition of lime; after treatment with lime, it dropped to an average of about 1:2.5, varying from 1:2.1 to 1:3.

While the results are somewhat irregular, and the special conditions causing these variations have not been studied, it is obvious that treatment with lime in diluted solution causes marked change in the character of the sulphide compounds present. Apparently, the higher sulphides (CaS_5) and (CaS_4) more or less largely decompose, forming sulphides containing less sulphur in proportion to calcium.

The chemical reaction explaining these changes is well known and has been referred to already. When polysulphides of calcium are treated with lime and water (CaO_2H_2), the

higher sulphides decompose, forming lower sulphides, sulphides containing less sulphur in combination with calcium, or, stated another way, more calcium in combination with sulphur.

From the point of view now generally held, though not experimentally established, that the pentasulphide of calcium (CaS_5) is the most effective compound in the lime-sulphur wash for destroying scale-insects, it is obvious that the loss in efficiency by conversion of this sulphide into lower forms along with formation of thiosulphate and free sulphur as a result of treatment with lime, may be considerable. Thus, for 100 pounds of sulphur in a concentrated wash there may be a loss of sulphide sulphur ranging from 12 to 36 pounds and averaging about 25 pounds; and, in addition to this, is supposed loss of efficiency by conversion of pentasulphide and tetrasulphide into forms of sulphide containing less sulphur. In fact, it can be seen that when a lime-sulphur wash is treated with lime before application, it is highly probable that little or no calcium pentasulphide or tetrasulphide is applied to the trees, but only lower forms, together with thiosulphate and free sulphur. This whole question of change of efficiency in the lime-sulphur wash as a scale destroyer can be determined only by practical work on the part of entomologists.

USE OF SEDIMENT IN MAKING LIME-SULPHUR WASH.

It has been customary to throw away the portion remaining undissolved in the preparation of the lime-sulphur wash. The question has arisen as to whether this sediment cannot be used again along with more sulphur and lime in making more of the sulphide mixture. Our data bearing on the composition of the sediment enable us to give some information on this point. The sediment consists largely of calcium sulphite ($CaSO_3$), free sulphur, hydroxide and carbonate of lime and, in case of impure limestone, more or less hydroxide and carbonate of magnesium. When lime of good purity (containing over 90 per ct. of calcium oxide, and not more than 3 or 4 per ct. of magnesium oxide) is used, there will ordinarily be economy in using the sediment again, in order to utilize the free sulphur and calcium hydroxide it contains. In the case of lime containing 5

per ct. or more of magnesium oxide, there would be an accumulation of magnesium compounds in the sediment, and the result of using the sediment repeatedly would not be good economy. The wise course is to use only commercial lime that is free from magnesium oxide or nearly so.

EFFECT OF USING MAGNESIUM OXIDE IN PLACE OF LIME IN THE LIME-SULPHUR MIXTURE.

In one experiment, magnesium oxide was substituted for lime, using 125 parts of sulphur and an amount of magnesium oxide equivalent to 65 parts of lime. The mixture thus prepared contained only a trace of sulphur in solution. Practically no reaction took place. The sediment contained 67.37 per ct. of sulphur, of which 66.73 per ct. was unchanged sulphur, there being a slight amount of sulphite and sulphate sulphur. In addition, the sediment contained about 20 per ct. of magnesium oxide. It was noticed that hydrogen sulphide (H_2S) gas was formed in considerable amounts.

It is evident, therefore, that magnesium oxide is not an available material for making soluble sulphides. When present in lime, it not only forms no sulphides but tends to decompose and decrease the amount of calcium polysulphides formed, and it causes some actual loss of sulphur through the formation and escape of hydrogen sulphide gas. In order to secure the most economical results in every way in making the lime-sulphur wash, it is highly desirable, therefore, to use lime as free as possible from magnesium oxide.

EFFECT OF ADDING MAGNESIUM OXIDE TO A DILUTED LIME-SULPHUR WASH.

A concentrated solution of lime-sulphur wash was diluted by addition of 9 parts of water, and magnesium oxide was added in an amount equivalent to 10 pounds of lime for 50 gallons of diluted solution. It was noticed, after adding the magnesium oxide, that hydrogen sulphide (H_2S) gas was freely given off. The following tabulated statement gives the amounts

of sulphur in various forms before and after adding magnesium oxide. The data are based on 50 gallons of diluted mixture.

TABLE XII.—EFFECT OF ADDING MAGNESIUM OXIDE TO LIME-SULPHUR SOLUTION.

Condition of mixture.	Total sulphur in mixture.	Sulphur in solution.		Sulphur in sediment.	Percentage of total sulphur.		
		In form of sulphides.	In form of thiosulphates.		In form of sulphides.	In form of thiosulphates.	In form of free sulphur.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*			
Untreated	10.15	9.70	0.45	0	95.6	4.4	0
Treated	10.15	8.65	1.05	0.45	85.2	10.3	4.5

The results show that under the conditions of the experiment, the addition of magnesium oxide to the diluted lime-sulphur wash decreased the amount of sulphide sulphur and increased the amounts of thiosulphate and free sulphur.

COMMERCIAL LIME-SULPHUR PREPARATIONS.

The samples of liquid commercial preparations were collected under the direction of Hon. Raymond A. Pearson, Commissioner of Agriculture. The special brands thus collected, which form the basis of our work, are the following: (1) "Rex," 3 samples; (2) "Grasselli," 3 samples; (3) "Niagara," 4 samples (4) "Thomsen," 2 samples. In addition to these, we have recently had placed in our hands a dry powder called "Never-Scale," which we will consider by itself.

GENERAL CHARACTER AND VALUE OF COMMERCIAL PREPARATIONS.

The various preparations were essentially alike in color, all being reddish-golden or orange-red when seen in a quart glass fruit-jar and deep claret when viewed in larger masses. Only

one brand, "Niagara," contained appreciable amounts of sediment. This appeared olive-green as seen in the mixture. The table together with the total percentage of sulphur in the specific gravity and Beaumé readings are given in the following mixture.

TABLE XIII.— SPECIFIC GRAVITY, ETC., IN COMMERCIAL PREPARATION.

Sample.	Name of brand.	Specific gravity.		Degrees Beaumé.		Amount of combined sulphur in mixture.
		Solution with sediment.	Solution without sediment.	Solution with sediment.	Solution without sediment.	
						Per ct.
A	Grasselli........	—	1.2933	—	32.7	25.68
B	"	—	1.2820	—	32.0	24.52
C	"	—	1.2810	—	31.8	24.47
D	Niagara........	1.280	1.2667	31.7	30.4	23.28
E	"	1.373	1.3119	39.4	34.5	25.43
F	"	1.380	1.2721	40.0	31.1	22.75
G	"	1.324	1.2770	35.5	31.4	22.87
H	Rex...........	—	1.2740	—	31.2	24.34
I	"	—	1.2960	—	33.0	25.60
J	"	—	1.2740	—	31.2	24.32
K	Thomsen.......	—	1.2270	—	26.8	18.73
L	"	—	1.3050	—	33.9	26.49

In examining the preceding table, it is noticed that the commercial preparations vary somewhat widely in respect to the amount of combined sulphur in solution, ranging from 18.73 to 26.49 per ct., though most of them are approximately between 23 and 25 per ct. The degrees Beaumé of the clear solution vary from 26.8 to 34.5. There is a fairly uniform relation between the degrees Beaumé and the amount of combined sulphur in solution; in general, one degree Beaumé corresponds approximately to 0.76 per ct. of combined sulphur in concentrated solutions within the limits of 25 to 33 degrees. On the basis of this average relation, we can calculate approximately the percentage of combined sulphur in solution corresponding to a given degree Beaumé within the limits of 25 and 33 degrees. From these and other data we can also estimate the

approximate relative cost of each pound of combined sulphur in solution on the basis of ten dollars for 50 gallons. In a solution containing about 24 per ct. of combined sulphur, each pound of sulphur costs 8 cents when 50 gallons sell for ten dollars. We can, therefore, estimate what the relative cost of 50 gallons is when the solution contains more or less sulphur than about 24 per ct. The various data here referred to are presented in the following table. These figures are given for sake of making comparison and not with any reference to actual market values.

TABLE XIV.—SHOWING RELATION OF DEGREES BEAUME, PERCENTAGE OF SULPHUR IN SOLUTION, COST, ETC.

Degrees Beaumé.	Combined sulphur in solution.	Cost of each pound of sulphur in solution.	Relative valuation of 50 gallons at 8 cents per pound of sulphur in solution.	Excess of cost (at $10 for 50 gallons) over actual value.
	Per ct.	*Cts.*		
25	19.00	10.50	$7.60	$2.40
26	19.80	10.00	8.00	2.00
27	20.60	9.50	8.40	1.60
28	21.30	9.10	8.80	1.20
29	22.00	8.75	9.20	0.80
30	22.80	8.40	9.60	0.40
31	23.60	8.00	10.00	0.00
32	24.30	7.75	10.40	—
33	25.00	7.50	10.80	—

COMPOSITION OF COMMERCIAL PREPARATIONS.

In Table XV are given the percentages of sulphur in different forms and of calcium in combination as sulphides which were found to be present in the samples examined. In the case of samples E–G, the percentages are based on the whole mixture, sediment and solution. In the other cases there was no appreciable amount of sediment.

TABLE XV.— PERCENTAGES OF CONSTITUENTS IN COMMERCIAL PREPARATIONS.

Sample	Name of brand.	Sulphur in mixture. Total.	In form of soluble sulphides.	In form of thiosulphates.	In form of free sulphur.	In form of sulphites and sulphates.	Calcium in combination as sulphides.	Ratio of calcium to sulphides sulphur.
		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Ca: S
A	Grasselli........	25.68	24.99	0.69	0	0	6.94	1 : 3.60
B	"	24.52	23.40	1.12	0	0	6.54	1 : 3.58
C	"	24.47	23.30	1.17	0	0	6.55	1 : 3.56
D	Niagara........	23.28	22.07	1.21	traces	traces	6.00	1 : 3.68
E	"	25.47	21.74	0.82	0.87	2.04	6.15	1 : 3.53
F	"	22.77	17.06	1.32	1.15	3.24	4.85	1 : 3.52
G	"	22.87	20.32	1.15	0.10	1.30	6.70	1 : 3.30
H	Rex...........	24.34	23.26	1.08	0	0	6.28	1 : 3.70
I	"	25.60	24.64	0.96	0	0	6.73	1 : 3.66
J	"	24.32	23.17	1.15	0	0	6.47	1 : 3.58
K	Thomsen.......	18.73	16.47	2.26	0	0	4.42	1 : 3.72
L	"	26.49	25.61	0.88	0	0	7.21	1 : 3.55

A study of the preceding table brings out the following facts:

(1) *Total sulphur.*—The total amount of sulphur in these commercial preparations varies from 18.73 to 26.49 per ct. Except in the case of samples E–G, the sulphur is all in solution; in these three samples the sulphur in the clear solution, freed from sediment, is 22.56, 18.38 and 21.47 per ct. respectively. It would appear from these data that one should reasonably expect a first-class concentrated commercial preparation to contain about 24 to 25 per ct. of total sulphur in solution.

(2) *Sulphur in soluble sulphide form.*— The amount of soluble sulphide sulphur varies from 16.47 to 25.61 per ct. In samples A—C and H—J, the amount of sulphide sulphur is fairly uniform, ranging within the limits of 23 and 25 per ct. A high grade commercial mixture should, therefore, be expected to contain over 23 per ct. of soluble sulphide sulphur. So far as our present knowledge goes, it is the soluble sulphide sulphur that is most effective in killing scale-insects and the amount of this form of sulphur constitutes the chief basis in estimating the efficiency of a lime-sulphur wash.

(3) *Sulphur in form of thiosulphates.*—The amount of thiosulphate sulphur, which is present mainly as calcium thiosulphate ($Ca_2S_2O_3$), varies in the commercial preparations under consideration from 0.69 to 2.26 per ct. It has already been pointed out (p. 358) that thiosulphate sulphur is usually formed at the expense of the sulphides, so that, in general, a high thiosulphate percentage is accompanied by a comparatively low sulphide percentage. The high amount of thiosulphate sulphur in sample K is probably due to incomplete boiling in making the preparation.

(4) *Insoluble sulphur.*—In samples E–G, free sulphur is present in amounts ranging from 0.10 to 1.32 per ct., and sulphite sulphur (mixed with small amounts of sulphate), in amounts varying from 1.30 to 3.24 per ct.

(5) *Calcium in sulphide compounds.*—The amount of calcium combined with sulphide sulphur varies from 4.42 to 7.21 per ct., running quite parallel in amount to the sulphide sulphur.

(6) *Calcium-sulphur ratio.*—The amount of sulphide sulphur in proportion to calcium in sulphide combination is fairly uniform, quite independent of other variations. This indicates that the sulphide sulphur is in the form of calcium pentassulphide (CaS_5) and tetrasulphide (CaS_4). These relations have been quite fully discussed on p. 369.

(7) *Comparison of commercial and home-made preparations.*—If we compare commercial and home-made lime-sulphur preparations, it is noticeable that the commercial preparations are somewhat more concentrated. Home-made preparations may contain 22 to 23 per ct. of combined sulphur in solution but rarely more, so far as our observations go. The best commercial preparations for the most part contain 24 per ct. and more of soluble sulphur in combined form. This greater concentration is caused by use of less water or by removal of some of the water from the liquid portion by evaporation.

SEDIMENT IN COMMERCIAL PREPARATIONS.

Of the commercial preparations examined, only one brand contained sediment in appreciable amounts and the percentage varied widely in the different samples. It was reported that in some cases the barrel was so filled with solid matter that the material would not run out. In the tables below we give the composition of the sediment and also the number of pounds of each constituent present in 50 gallons. The specific gravity of the sediment in these cases varied from 2 to 2.25, averaging about 2.15, making one gallon weigh about 18 pounds.

TABLE XVI.— COMPOSITION OF SEDIMENT IN COMMERCIAL PREPARATIONS.

Sample.	Total. sediment.	Sulphur.				Calcium	Magnesium.	Iron and aluminum.
		Total.	Free.	In form of sulphite.	In form of sulphate.			
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
D	0.43	17.03	—	—	—	17.78	9.37	2.27
E	12.82	22.69	6.75	13.97	1.97	15.73	11.58	1.08
F	19.35	22.67	5.93	15.71	1.03	16.37	11.14	1.77
G	8.16	16.92	0.88	15.60	0.44	15.20	12.75	1.05

It is a matter of interest and importance to learn what constituents are present in the sediment of the preparation in question, expecially since peculiar value as a scalecide has been persistently claimed for such sediment. The analytical data show,— (1) that the sulphur is more largely calcium sulphite than any other form and (2) that a considerable portion of the remainder consists of magnesium, with small amounts of iron and aluminum compounds. The iron may be present in the form of sulphide and, if present in sufficient amount, imparts to the sediment when dried a grayish color. Magnesium and aluminum are present mainly as hydroxides. The amounts of magnesium, iron and aluminum present in a sediment depend upon the amounts of those constituents in the lime used. It is evident from the composition of the sediment found in the

preparations under discussion that a lime was used containing considerable magnesium compounds and other impurities.

When we consider the character of the compounds found in the sediment, there is no reason whatever for believing that the value of the mixture is peculiarly enhanced by the presence of this insoluble matter; but that, on the other hand, the value to the fruit-grower is lessened, because the amount of soluble sulphides contained in a barrel is considerably less by reason of the presence of the sediment. To what extent the sediment constitutes a part of 50 gallons of mixture may be seen from the table following:

TABLE XVII.—SEDIMENT IN 50 GALLONS OF PREPARATION.

SAMPLE.	Weight of 50 gallons.	Weight of sediment in 50 gallons.	Sulphur. Total.	Sulphur. In form of free sulphur.	Sulphur. In form of sulphite.	Sulphur. In form of sulphate.	Calcium.	Magnesium.	Iron and aluminum.
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
D.......	533.9	2.3	0.4	—	—	—	0.4	0.2	0.0
E.......	572.5	73.7	16.7	5.0	10.3	1.4	11.6	8.5	0.80
F.......	575.0	111.0	25.2	6.6	17.5	1.1	18.2	12.4	2.00
G.......	552.0	45.0	7.6	0.4	7.0	0.2	6.8	5.7	0.50

In sample F the sediment constitutes 20 per ct. (by weight) of the contents of a 50 gallon barrel. Such material is obviously not economical to purchase when clear solutions, free from sediment, containing higher percentages of soluble sulphides, are on the market at the same price.

"NEVER-SCALE"

"Never-Scale" is placed on the market in the form of a fine powder. An analysis of a sample gives the following results:

Constituents.	*Per ct.*
Moisture	2.65
Total sulphur	30.55
Combined sulphur soluble in water at 70° F	6.15
Free sulphur	19.70
Sulphite sulphur	4.70
Total lime (CaO)	24.69
Magnesium oxide	14.64

Other constituents were present in small amounts but are of no interest in relation to the lime-sulphur wash. It appears from analysis to be largely a mixture of free sulphur and lime containing a considerable amount of magnesium oxide.

The material is used in preparing the lime-sulphur wash by mixing at the rate of three-quarters of a pound for one gallon of boiling water and boiling three to five minutes. It would therefore require 37.5 pounds of the powder to make 50 gallons of mixture of proper strength for spraying.

A solution was prepared according to the directions given. Of the powder used, about 38 per ct. did not go into solution. The filtered solution contained about 3.75 per ct. of soluble combined sulphur and 2 per ct. of calcium. The sediment contained 30.24 per ct. of sulphur, mostly free, about 20 per ct. of calcium oxide, and nearly 34 per ct. of magnesium oxide. In the descriptive circular, the statement is made that the sediment consists largely of lime, which does not agree with our results of analysis. If a purer form of lime were used, more efficient results could be obtained. Apparently, a much larger proportion of the sulphur remains uncombined than in the preparation of the regular home-made lime-sulphur wash.

The cost of the material is five cents a pound, with a reduction of price for large purchases. At the maximum rate of five cents a pound, 50 gallons of the wash ready to apply to trees, prepared with this powder, cost $1.875, counting only the cost of the preparation used. Compared with concentrated commercial lime-sulphur washes at ten dollars for 50 gallons, which amount makes 450 gallons of wash ready to apply to trees, the "Never-Scale" wash is considerably more expensive, assuming that it is of equal value in destroying insects. To make 450 gallons of spraying solution with "Never-Scale" would require an amount which, at five cents a pound, would cost $16.875. In order to approximate the same cost as concentrated commercial solutions of good grade, "Never-Scale" would need to sell at about three cents a pound and this does not make any allowance for the cost of boiling the mixture.

LIME AND LIMING.*

L. L. VAN SLYKE.

THE USE OF LIME COMPOUNDS ON SOILS.

Numerous inquiries in regard to the use of lime-containing materials are constantly coming to the Station. In order to answer these inquiries more fully than can be done in individual correspondence, this circular has been prepared.

The different lime compounds to be considered are used for the purpose of (1) neutralizing the acidity of soils, (2) producing other changes, chemical, biological and physical, (3) supplying phosphorus to plants or (4) furnishing calcium to plants. Lime compounds are least often used for the direct supply of calcium as plant-food because this element is sufficiently abundant in most soils to supply crops. For neutralizing the acidity of soils there are used *lime*, *slaked lime* and *carbonate of lime.* For producing other changes in soils the same lime compounds are used and, in addition, *sulphate of lime* (land-plaster). The two materials which will be discussed as a source of phosphorus are *ground phosphate rock* (floats) and *phosphate slag.* The slag also contains lime in other forms than phosphate and can be used for neutralizing soil acidity, while the rock has little, if any such value.

COMPOSITION OF LIME COMPOUNDS.

All lime compounds contain as a characteristic constituent the chemical element *calcium* and in chemistry are known as calcium compounds, as explained below. In the different compounds of lime we find calcium combined with one or more other chemical elements.

* A reprint of Circular No. 10.

LIME.

The word *lime* is ordinarily used to designate a compound consisting, when pure, of calcium (71.5 per ct.) and oxygen (28.5 per ct.), which is known to chemists as *calcium oxid* (CaO). At one time it was supposed that calcium oxid (lime) was present in the different compounds of calcium, and so all calcium compounds were called lime compounds. This inaccurate use has continued, especially in commercial practice. Calcium oxid, in impure forms, is known under several commercial names, such as *lime, quicklime, burntlime, stone-lime, lump-lime,* etc. The value of commercial lime depends, for many purposes, upon its freedom from impurities, that is, upon the amount of calcium oxid it contains.

Commercial lime is prepared by heating at a sufficiently high temperature any form of carbonate of lime (calcium carbonate), the carbon dioxid (carbonic acid) being driven off as a gas and calcium oxid remaining as a solid residue. The materials most commonly used as a source of commercial lime are limestone, oyster shells and shell-marl. It is evident that the purity of a lime (the percentage of calcium oxid present) depends upon (1) the purity of the original carbonate rock used, (2) the completeness of the burning, and (3) subsequent care in keeping dry. The impurities commonly found in commercial lime are compounds containing magnesium, silicon, iron, and aluminum. The three most common forms of commercial lime are: (1) Stone-lime, (2) magnesian stone-lime, and (3) oyster-shell lime.

Stone-lime. This is the ordinary lump-lime commonly used by masons. It is prepared from limestone (calcium carbonate) of a good degree of purity and contains 90 to 98 per ct. of calcium oxid.

Magnesian stone-lime. This is prepared from limestone that contains more or less magnesium carbonate, the proportions varying greatly in different varieties. Commercial lime prepared from such material contains 55 to 85 per ct. of calcium oxid and 10 to 40 per ct. of magnesium oxid. The presence of

magnesium compounds affects the slaking properties of lime, as pointed out below.

Oyster-shell lime. Oyster-shells contain 90 to 95 per ct. of calcium carbonate and, when properly burned, produce a high-grade lime, containing from 85 to 95 per ct. of calcium oxid.

In addition to the preceding forms of commercial lime, one other of less importance may be mentioned, known as *gas-lime.* Quicklime is used at gas-works to remove impurities from the gas and after being so used it is often sold to farmers. Gas-lime is not quicklime, since the calcium oxid is largely changed into other forms such as hydroxid (slaked lime) and carbonate. In addition, there are the impurities absorbed from the gas, some of which are injurious to seeds, such as sulphids and sulphites. These are changed into the harmless form of sulphate (land plaster) on exposure to the air. Gas-lime should, therefore, when used on soils, be allowed to lie exposed to the air before use or should be put into the soil some weeks or months before putting in a crop. The composition of gas-lime varies greatly.

SLAKED LIME.

When quicklime undergoes the change known as *slaking*, its calcium oxid (CaO) combines with water (H_2O) and is changed into a compound known chemically as *calcium hydroxid* (CaO_2H_2) or, commercially as *slaked lime, caustic lime,* or *hydrated lime;* one pound of calcium oxid combines with about one-third of a pound of water and produces one and one-third pounds of calcium hydroxid (slaked lime). This chemical change is accompanied by marked physical changes; the lime swells in bulk, crumbles to a fine powder and generates heat. The rapidity with which commercial lime slakes depends upon the amount of water used and the composition of the quicklime. The use of too much water or the sudden chilling of partially slaked lime by cold water results in the production of a coarse, granular lime in place of the desired form of fine powder. Commercial limes containing less than 10 per ct. of impurities slake more quickly than those con-

taining larger amounts of impurities. Magnesian stone-limes slake imperfectly.

One bushel of stone-lime of good quality, on slaking, increases in bulk to two or three bushels of slaked lime. The weight per bushel decreases roughly about one-half, for example, from 90 to 45 pounds. The bulk and weight of slaked lime depend upon the composition of the quicklime used, upon the amount of water added, and upon some special conditions of the slaking process.

The calcium hydroxid of slaked lime easily absorbs carbon dioxid gas from the air and changes gradually into calcium carbonate. Just as quicklime is impure calcium oxid, so slaked lime is impure calcium hydroxid. Ordinary slaked lime is, therefore a mixture of calcium hydroxid and calcium carbonate with such impurities as may have been present in the lime before slaking.

The slaking of lime also takes place when lime is exposed to the air, this process being known as *air-slaking*. When lumps of stone-lime stand exposed for some time, the outer layer gradually absorbs moisture from the air and goes through the process of slaking and forming a fine powder. In the air-slaking process, more or less calcium carbonate is also formed. Hence, air-slaked lime usually contains larger amounts of carbonate and less of hydroxid than water-slaked lime. The rapidity with which limes air-slake depends upon different conditions. Dry, fine air-slaked lime may contain as much as 75 per ct. of calcium oxid.

CARBONATE OF LIME.

Carbonate of lime is chemically known as *calcium carbonate.* In this form calcium oxid (CaO) is combined with carbon dioxid (CO_2), thus forming calcium carbonate ($CaCO_3$). Limestones of high grade and marbles consist largely of calcium carbonate. It forms varying proportions of shells, marl, etc. As previously stated, it is present in variable amounts in slaked lime.

SULPHATE OF LIME.

This material is known in chemistry as *calcium sulphate;* its common names are *land-plaster* and *gypsum.* It is a compound of calcium and sulphuric acid. It possesses value on the farm because it is an excellent absorbent and also because it may undergo chemical changes in the soil as a result of which insoluble potash compounds are made soluble. In dissolving rock phosphates (phosphate of calcium) with sulphuric acid, a considerable amount of calcium sulphate is formed. Commercial acid phosphates, therefore, contain more or less sulphate of lime.

WOOD ASHES.

Wood-ashes vary greatly in composition. When of good quality, they should contain not less than 35 per ct. of calcium oxid, 3 per ct. of magnesium oxid and 5 per ct. of potash. These compounds are present largely in the form of carbonates.

COMPARATIVE COMPOSITION OF LIME COMPOUNDS.

It is a matter of interest and importance to compare the principal lime compounds with reference to the amount of calcium oxid contained in them. This is shown in the following arrangement:

FORM OF LIME COMPOUND.	Lime (CaO)	Water (H_2O)	Carbon dioxid CO_2
	Per ct.	*Per ct.*	*Per ct.*
Calcium oxid (lime)	100	——	——
Calcium hydroxid (slaked lime)	75.7	24.3	——
Calcium carbonate (carbonate of lime)	56	——	44

It is seen that 100 pounds of pure lime (CaO) contains 100 pounds of calcium oxid; that 100 pounds of pure slaked lime (calcium hydroxid) contains an amount of calcium equivalent to about 76 pounds of calcium oxid; and that 100 pounds of carbonate of lime contains an amount of calcium equivalent to 56 pounds of calcium oxid. This means that one pound

of calcium oxid (lime) is equal to about 1.3 pounds of calcium hydroxid (slaked lime) and to about 1.8 pounds of carbonate of lime.

WEIGHT OF A BUSHEL OF LIME.

It is the custom in some places to sell lime by the bushel. It should be sold only by weight, because the weight of a bushel varies greatly according to a variety of conditions, chief among which are porosity of the limestone burned and the conditions of burning. The average weight of a bushel (heaped measure) of stone-lime is given as 75 to 93 pounds, but it may vary from 60 to 120 pounds. Magnesian stone-lime usually runs somewhat lower. Oyster-shell lime varies from 40 to 75 pounds a bushel and averages about 60.

WHAT LIME COMPOUNDS DO IN SOILS.

Lime compounds, when applied to soils, produce certain specific effects, which, for convenience, may be considered under three heads: (1) Chemical, (2) biological, and (3) physical. These will be considered in brief outline.

CHEMICAL EFFECTS.

The direct chemical effects of lime compounds in soils may be conveniently grouped under two general heads: (1) Rendering available some insoluble forms of plant-food, especially in case of certain compounds containing potassium or phosphorus; and (2) neutralizing excessive acidity of soils. Lime in the forms of quicklime, slaked lime and carbonate has the power to neutralize acids but sulphate of lime (land-plaster) has not. The rapidity with which soil acidity is neutralized depends primarily upon (a) the fineness of the lime compound and (b) the thoroughness with which it is distributed through the soil.

BIOLOGICAL EFFECTS.

The lime compounds previously mentioned tend to make conditions favorable for the action of certain important micro-

organisms in soils. These effects may be grouped under three general divisions: (1) Promotion of the decomposition of organic matter, including the process of nitrification; (2) making conditions favorable for the nitrogen-gathering organisms associated with leguminous plants; and (3) favoring the growth of those soil organisms that utilize atmospheric nitrogen independently of other plants.

The presence of lime compounds, especially quicklime and slaked lime, hasten the conversion of organic matter into humus, with the changing of the nitrogen into nitrates. Organic matter in decomposing produces acids quite freely, which may render a soil acid when they are allowed to accumulate without being neutralized. In the presence of the neutralizing forms of lime, these acids are converted into neutral lime compounds and soil acidity prevented. Nitrifying and nitrogen-gathering organisms do not grow satisfactorily in acid soils but appear to require for their best development a neutral or slightly alkaline condition. When applied in excessive quantities, quicklime and caustic lime hasten the decomposition of organic matter by direct chemical action. By applying these forms of lime too frequently or in too large quantities, it is possible to exhaust the supply of humus rapidly, unless unusual methods of supplying humus are utilized.

PHYSICAL EFFECTS.

Chemical changes produced in soils by lime compounds result in producing physical changes. In general, it may be said that lime compounds lighten heavy soils and compact light soils. Clay soils are made less sticky, more crumbly, and more easily cultivated; water passes through them more readily and, in general, such a soil becomes a more congenial place for the growth of plant roots. On sandy soils, lime compounds tend to act like cement in holding the soil particles together, thus enabling them to hold water more tenaciously.

EFFECTS OF LIME ON DIFFERENT PLANTS.

While no rigid rules can be laid down for general application to all conditions, the Rhode Island experiment station has found that most of our common crops are benefited by the use of lime compounds; some plants appear to be unaffected, while a few (watermelon, serradella, blue lupine and sheep-sorrel) are injured. The application of quicklime, slaked lime and wood-ashes is found to promote potato-scab when applied in amount sufficent to remove completely the acidity of the soil. Excessive applications of quicklime or of slaked lime may cause decreased growth of crops for one season but increased growth afterwards.

HOW TO ASCERTAIN WHETHER A SOIL NEEDS LIME.

Two methods can be used to ascertain whether a soil needs lime (1) The litmus test for acidity, and (2) the growth of red clover. The litmus test is performed as follows: Blue litmus-paper of the best quality, or, preferably, very sensitive neutral litmus-paper, in strips about one-half inch wide and two inches long, is used. This can be obtained at drug-stores. Put in a cup a tablespoonful or more of soil and moisten with water enough to make a thick paste. After letting the soil stand a half hour or more, a clean table-knife is inserted to part the soil, and one end of the litmus-paper is put into the opening thus made, after which the soil is pressed against the sides of the paper. In a half hour to an hour after, the paper is carefully taken from the soil without tearing. The adhering soil is rinsed off the paper. If the original blue color is changed to a distinct red or pink, acidity is indicated that calls for the use of lime. The end of the litmus-paper that is inserted into the soil must not come in contact with the hands and the water used must be neutral (neither acid nor alkaline). It should be stated that cases appear in which the litmus test gives unreliable indications.

The need of lime is usually indicated when the common red clover after starting vigorously in the spring appears later to stand still in growth and finally disappears in part or wholly. A vigorous growth of horse-sorrel is commonly a sign of the need of lime.

HOW MUCH LIME TO APPLY AND HOW OFTEN.

The character of the soil and the crops grown must determine largely the amount of lime to use. The general rule may be safely followed of applying lime in smaller quantities at more frequent intervals rather than large quantities once in several years. On poor soils and in case of light, dry soils, the quantity applied at one time should be relatively small, varying from 500 to 1,500 pounds of quicklime per acre, and corresponding amounts of other forms. However, in the case of carbonate of lime, three or four times as much can be used to advantage. On heavy clay soils and on rich soils, the application may vary from 1000 to 4000 pounds according to frequency, acidity, etc. In rotations of five or six years, one liming will probably suffice for the rotation under ordinary conditions. On meadows kept in grass for many years in succession and fertilized exclusively by commercial fertilizers, application of lime on the surface at the rate of 300 to 500 pounds an acre once in three or four years will usually be found helpful.

AT WHAT TIME TO APPLY LIME.

Autumn is the best time to apply quicklime or slaked lime on land used for spring crops. The power of quicklime or slaked lime to injure seeds is gradually lost by lying in the soil. In case of autumn seeding, the lime can be scattered after plowing and then harrowed in very thoroughly. For many crops, lime may be applied in the spring with little risk, provided it is worked into the soil very completely. In case of very sour soils, the application of lime in the spring is often very beneficial. Carbonate of lime can be applied at any time without risk of injury to crops.

WHAT FORM OF LIME TO USE.

Of the various forms of lime available, it will usually be found in this State that stone-lime* will prove cheapest, since it is in the most concentrated form. This is especially true when the material has to be freighted or drawn a considerable distance. In 2,000 pounds of quicklime, there is as much calcium oxid as in 2,600 pounds of slaked lime or in 3,600 pounds of carbonate. There are in the market, lime materials which are sold under various names, as agricultural lime, prepared lime, hydrated lime, etc. These are in some cases slaked lime and in others carbonate. They are usually sold at prices considerably higher than stone-lime and often extravagant claims are made for their superior merits. *Farmers are advised not to purchase these much-advertised materials,* since they are needlessly expensive. One party, for illustration, offers a slaked lime for $8 a ton and quicklime for $5. The calcium oxid in the quicklime thus costs one-quarter of a cent a pound, and, in the slaked lime, more than twice as much. When quicklime can be purchased at $5 a ton, it is not profitable to pay more than $3.75 to $4 a ton for slaked lime, or more than $2.75 to $3 a ton for carbonate. The hydrated materials have this one advantage over stone-lime, that the labor of slaking the lime is saved; but farmers can not, under the circumstances, more profitably employ their time than in slaking the lime themselves.

Lime, properly slaked and dry, forms a finer powder than is possible with the ground carbonate, and it can be more uniformly distributed through the soil. Moreover, freshly-slaked quicklime consists largely of calcium hydroxid, which is more easily soluble in water than the carbonate. This solubility is

* Stone-lime can be furnished by the following parties: New York Lime Co., Carthage, N. Y.; Genesee Lime Co., Honeoye Falls, N. Y.; Ohio and Western Lime Co., Fostoria, Ohio; M. E. Reeder, Nursery, Pa.; C. H. Coons, Germantown, N. Y.; Rochester Lime Co., 209 W. Main St., Rochester, N. Y.; Catlin and Miller, Owego, N. Y.; John Heimlich, Le Roy, N. Y.; J. E. Reichard, Bloomsburg, Pa. These addresses are given solely as a matter of information, without recommendation or guarantee as to reliability.

an important factor when a freshly-limed soil receives abundance of rain, because considerable amounts of the hydroxid go into solution and thus are more quickly and uniformly distributed through the soil.

At the prices usually prevailing ($10 to $12 a ton), one can not afford to use wood-ashes for neutralizing soil acidity. As compared with the average cost of potash and lime, wood-ashes of high commercial grade can hardly be regarded as worth more than $7 to $8 a ton. On account of the potassium carbonate present, wood-ashes are more efficient than lime in compacting very light soils.

HOW TO APPLY LIME TO SOILS.

In applying lime to soils, three facts should be kept in mind: (1) The lime should be distributed for the most part in the upper layer of the soil, say within three or four inches of the surface; (2) it should be distributed as uniformly and thoroughly as possible through the soil; (3) in case of quicklime, it should be put into the soil while mostly in the form of slaked lime or hydroxid and before being changed more than slightly into carbonate.

The most convenient form of lime to handle is probably the ground quicklime, which is furnished for building purposes and which can usually be distributed with a fertilizer drill. There are, however, special lime-spreaders which are more convenient.

Freshly burned lump-lime may be slaked in a large pile near the field and then distributed; but when one has no special means for distributing the slaked lime, it is more convenient under ordinary conditions to distribute the lump-lime in small piles over the field after the land is prepared for a crop. A little water (equal to about one-third the weight of the lime) is slowly poured on each heap and the lime then covered with fine earth. When thoroughly slaked, the powder is mixed with more earth and distributed with a shovel as evenly as possible, after which it is promptly harrowed into the soil very thor-

oughly. The size and frequency of the heaps of lime may be regulated by remembering that 20-pound heaps placed 20 feet apart make about one ton to the acre. After being spread, lime should not be allowed to lie upon the surface over night or during showers.

GROUND PHOSPHATE ROCK OR FLOATS.

Rock-phosphates are known under different names, which generally designate the localities from which they come, as, for example, South Carolina Rock, Florida Rock, Tennessee Rock, etc. When ground to a very fine flour, the rock-phosphate is called floats. The phosphoric acid in these materials is largely in combination with lime as insoluble phosphate of lime (calcium phosphate), commercially called "bone phosphate of lime." This material when treated with sulphuric acid forms a mixture of acid phosphate and sulphate of lime, commercially known as dissolved rock, acid phosphate, etc. The phosphoric acid in phosphates usually runs from 20 to 25 per ct. but may go as high as 35 to 40 per ct. Rock-phosphate in the form of floats* possesses little if any value in neutralizing the acidity of soils. When used by farmers, it is for the purpose of supplying to crops the plant-food element phosphorus. Several experiment stations, notably among them those of Illinois and Ohio, have shown some of the conditions under which floats can be used to advantage as a source of phosphorus. It can be stated, in general, that, when used in connection with liberal

*The Illinois experiment station, without making recommendations as to reliability or guarantee, states that floats containing 25 to 30 per ct. of phosphoric acid, can be obtained from any of the following parties: (1) Mt. Pleasant Fertilizer Co., Mt. Pleasant, Tenn.; (2) Robin Jones, Nashville, Tenn.; (3) N. Y. & St. L. Mining & Mfg. Co., St. Louis, Mo.; (4) Swan Creek Phosphate Co., Chicago, Ill.; (5) Jackson Phosphate Co.; Mt. Pleasant, Tenn.; (6) Farmers Ground Rock Phosphate Co., Mt. Pleasant, Tenn.; (7) John Ruhm, Jr., Mt. Pleasant, Tenn.; (8) H. D. Ruhm & Co., Mt. Pleasant, Tenn.; (9) W. B. Alexander & Co., Mt. Pleasant, Tenn. The cost is $2.50 to $5.00 a ton, according to percentage of phosphoric acid, delivered in bulk on board cars at the mines in Tennessee. The material would probably cost $8 to $10 a ton in New York State.

amounts of farm-manure or green manures, or both, ground rock-phosphate is one of the most economical forms in which to supply phosphorus to crops. Its use is not recommended on soils deficient in organic matter or where it is desired to have the phosphorus at once available for the growing crop; in such cases, the use of dissolved rock (acid phosphate) or bone-meal is necessary. The effect of floats on crops is least marked the first season but becomes more pronounced later. Floats can be used to advantage as a mechanical absorbent in the stable using about one pound a day for the manure of each animal. It can, if preferred, be mixed with the manure after removal from the stable or spread on the field with manure, about 100 pounds of floats being used for 1,000 pounds of manure. The amount of floats to be used on soils may vary from 500 to 2,000 pounds an acre. When applied in a regular crop rotation, it may be used once in three to six years at the rate of 1,000 or 2,000 pounds an acre; it should under these conditions be applied to clover-sod or to a green crop, such as cow-peas, soy-bean, etc., which is to be plowed under.

SLAG-PHOSPHATE.

This material is known under different names, as odorless phosphate, basic iron slag, Thomas slag, etc. It is a by-product formed in the manufacture of iron and steel from special kinds of iron ore that are rich in phosphorus. It contains 15 to 20 per ct. of phosphoric acid, not all in quickly available form, and considerable amounts of lime and oxid of iron. Most of this material at present offered for sale is imported from Europe. The practical results coming from its use have been variable, often being excellent and again indifferent. The present price appears to be high. It is certain that the lime in it which is available for neutralizing soil acidity can be obtained much more cheaply. Before purchasing largely of this material, farmers are advised to use it in an experimental way in comparison with floats, with and without the lime compounds that neutralize acidity.

REPORT

OF THE

Department of Entomology.

P. J. Parrott, *Entomologist.*
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REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

THE TUSSOCK MOTH IN ORCHARDS.*

W. J. SCHOENE

SUMMARY.

During the past summer the white-marked tussock moth appeared in destructive numbers in orchards in the vicinity of Lockport. In this outbreak considerable damage was done to young apple and pear fruits by the caterpillars.

The tussock moth is not a new insect. It is a well known pest of shade trees in cities and towns. Although it may thrive on fruit trees it seldom appears in destructive numbers in orchards.

The insect may be efficiently controlled by collecting and destroying the egg masses and by the use of arsenical sprays.

* A reprint of Bulletin No. 312.

INTRODUCTION.

During the summer of 1908, the tussock moth (*Hemerocampa leucostigma* A. & S.) appeared in more than its usual numbers in the rural districts of western New York. A noteworthy feature of this outbreak was the presence of the caterpillars in orchards in several communities, where they did considerable damage to young fruits. While injuries to orchards are not of unusual occurrence, this insect is primarily a shade-tree pest. It is commonly associated with towns and cities, rather than with the country, and because of its importance to tree planting in municipalities, it is a familiar insect, at least by name, to many readers. Its attacks on fruit trees have attracted less attention. The present interest of fruit growers in this insect has prompted the publication of this bulletin, which deals largely with the tussock moth as an orchard pest.

ECONOMIC IMPORTANCE OF THE TUSSOCK MOTH.

PRESENT OUTBREAK IN ORCHARDS.

On June 10 letters began to arrive at the Station, announcing that an unknown pest had made its appearance in western New York, which was especially destructive to the young fruits. The arrival of specimens of the caterpillar soon proved that the real miscreant was the tussock moth. Samples of its work were received from many localities in our leading apple growing counties but the most damage was done by this insect in the vicinity of Lockport, Ransomville and Middleport. The work of the caterpillars was first noticed by fruit growers on June 8 and during the following week the principal injuries were done. In company with Mr. B. D. Van Buren, a State Inspector of Nurseries, an examination was made on June 11 of a number of orchards where the insect was especially destructive. At this time the caterpillars were in the first, second and third stages, and, contrary to expectations, were

PLATE XXII.—INJURIES TO APPLES BY TUSSOCK MOTH CATERPILLARS

causing important injuries in sprayed as well as in neglected orchards.

The caterpillars as a rule were not equally numerous on all trees in an orchard, so that the injury varied with the individual trees. On some portions of trees 85 per ct. of the fruit had been eaten into, while on other trees the amount of damaged fruit varied from 5 per ct. to 20 per ct. While there were some injuries to the leaves, the foliage was generally abundant, and unless a close examination was made, the appearance of the trees at this date completely deceived one as to the presence of the caterpillars. Also one was impressed with the large number of damaged fruits, which seemed out of proportion to the numbers of caterpillars actually present. The feeding was largely confined to the cheeks of the young apples and pears. In some instances only the skin of the fruit was consumed, but more damage was done by the worms eating out cavities of varying size and depth. Pears generally suffered more injury than apples, the cavities often extending through to the core so that only about half of the original fruit remained.

CONDITIONS IN SPRAYED ORCHARDS.

Upon the discovery of the caterpillars and the injuries to the fruit, some orchardists attempted to prevent further losses by spraying with arsenicals. Wherever a thorough treatment of bordeaux mixture containing a strong dose of poison was applied, a goodly percentage of caterpillars was killed and the poison continued to be effective, gradually reducing their numbers. But while the caterpillars were finally destroyed, they continued to feed to a greater or less extent for several days after the applications, during which time the amount of damage to fruits greatly increased. It appeared that the caterpillars, feeding in the deeper cavities of the injured fruits, found food that was not reached by poisons, and the insects were apparently not destroyed until they changed their feeding grounds.

The failure to prevent losses to the fruit by the usual treatments for the codling moth and apple scab, and by special sprayings, has led some fruit growers to conclude that the tussock moth caterpillars cannot be killed by applications of arsenical poisons. The large numbers of damaged fruits in orchards that were sprayed one or more times would tend to support this belief. However, an examination of a number of orchards at the time of the appearance of injuries indicated that the principal reason why spraying was not generally successful was the lack of thoroughness in the first treatments. This was especially emphasized by the fact that, preceding the attack of the tussock moth, case-bearers had caused in many of these same orchards more than their usual amount of injury, which should have been prevented if the poisons had been well applied. The orchardist in his efforts to drive the poisonous spray into the leaf and blossom clusters is liable to neglect the undersides of the leaves, especially on the lower and inner portions of the trees where the tussock moth caterpillars, on hatching, are likely to feed. Thus, even in orchards where the spraying for the codling moth has been fairly well done, the young caterpillars may feed unharmed for a time on the under surfaces of leaves, and on the foliage of water sprouts on the larger limbs.

HISTORY OF TUSSOCK MOTH AS A FRUIT PEST.

The early records on the habits of the white-marked tussock moth indicate that it was a general feeder, and that it thrived on fruit trees, shade trees and shrubs. In 1828 Harris recorded the caterpillars as very numerous on fruit trees throughout New England.[1] Again in 1832 the eggs of this insect were observed on apple trees about Salem, Mass., by B. Hale Ives, who in the following year proved experimentally that collecting and destroying the egg masses is an effective means for controlling this insect.[2] Fitch[3] reported in

[1] Harris, "Insects Injurious to Vegetation," p. 367.
[2] *American Gardeners (Hovey's) Magazine,* 1:52.
[3] Fitch. Rpts. 6–9, p. 199.

1863 that the moth had been in Albany for several years and that rose bushes and large plum trees were stripped of their foliage. Rev. C. J. S. Bethune[4] in 1871 considered this species a serious enemy to the apple trees in Ontario, and stated that in the West it had defoliated some orchards and had attacked the fruits. A serious outbreak of this kind was reported in 1895, by Mr. V. H. Lowe,[5] Entomologist of this Station, who received numerous complaints from the growers of Yates and Ontario counties of injuries to young apples. In succeeding years the presence of the caterpillar has been noticed in many orchards but as a rule there has been very little damage to the foliage and fruit until the present outbreak.

THE TUSSOCK MOTH AS A SHADE-TREE PEST.

It is in the cities and towns that the tussock moth finds congenial surroundings and there it thrives and proves most injurious. As early as 1848 Harris[1] reported that the caterpillars damaged the horse chestnuts and other trees about Boston. In 1883[6] shade trees in some of the parks of New York City was defoliated. In 1895 Dr. Howard[7] noted that the moth had been for many years the most serious of the shade tree pests in Philadelphia, New York, Brooklyn, and Boston, and that the caterpillars of this species had appeared that year in Washington, Baltimore and other southern cities in such numbers as to make the insect of great importance.

Dr. Felt[8] has recorded serious outbreaks of this pest in the State of New York during 1898. In Albany, spraying operations, conducted by the municipal authorities, were necessary to prevent general defoliation of the horse chestnuts. In some parts of Troy and in Buffalo the insect was still more destructive. These depredations have occurred so frequently along the streets and in the parks of some of our cities that spraying

[1] Harris: "Insects Injurious to Vegetation," p. 367.
[4] Entomological Society of Ontario. Report 1871–1872, p. 14, 15.
[5] N. Y. Agr. Exp. Sta. 14th Rept. 1895, p. 552–553.
[6] *Canadian Entomologist*, **15**:168, 169.
[7] U. S. Dept. Agr. Year Book, 1895, pp. 368, 375.
[8] E. P. Felt. 14th Rpt. State Ent. 1898, pp. 163, 176.

operations are now annually carried on for the protection of the trees.

DISTRIBUTION OF MOTH AND FOOD PLANTS.

The tussock moth is known to occur from Nova Scotia to Florida and as far west as the states of the Mississippi Valley. It feeds to a greater or less extent upon nearly every fruit and shade tree. In the outbreak of the past season, both the fruit and foliage of apples and pears were eaten and also the foliage of plums. Other fruits liable to attack are cherry, quince, apricot and choke cherry. The various shade trees[9] that the caterpillars are known to feed upon are horse chestnut, elm, maple, linden, box elder, locust, ash, sycamore, butternut, black walnut, hickory, oak, birch, elder, willow, poplar, spruce, fir, larch and cypress.

BIOLOGY OF TUSSOCK MOTH.

LIFE STAGES.

Egg.— The eggs are deposited on the empty cocoon in masses of from 100 to 500, and are held together and protected by a white foam-like substance, which renders the egg mass conspicuous in its resting place upon the trunk and branches of the tree. The individual egg is round, about the size of a mustard seed, and has a strong, thick, cream-colored shell.

Mature caterpillar.[10]— The head and two small tubercles on the back are bright red. There are three long black pencils

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[9] Memoir N. Y. State Museum. 8, I: 136.

[10] The caterpillar of this species has four stages in the male and five stages in the female. These may be recognized by the following brief descriptions taken from C. V. Riley's account in his first report on the Insects of Missouri, pp. 144–147. 1869.

First stage. Newly hatched. Length one-tenth inch, color dull whitish gray, tufts on back dark brown.

Second stage. Age of caterpillar seven days. Length one sixth inch, color more pronounced. Two tufts near head, longer.

Third stage. Age thirteen days. Length three-tenths inch. Color of head and neck shield, orange, tubercles on back scarlet orange, four tufts on back whitish. About five days after molt, colors of adult are assumed.

Fourth stage. Age nineteen days. Length three-fourths inch. Colors and hairs same as adult. Male larvæ spin cocoons.

Fifth stage. Age twenty-five days. Length, one and one-half inches. Colors unchanged. Hairs more prominent. Caterpillars mature to females.

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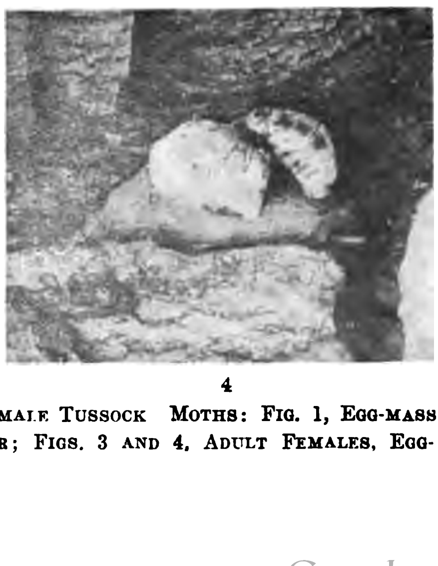

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Plate XXIII.— Life Stages of Female Tussock Moths: Fig. 1, Egg-mass on Cocoon; Fig. 2, Caterpillar; Figs. 3 and 4, Adult Females, Egg-masses and Cocoons.

of hairs, two extending V-shaped over the head and one diagonally upward from the anal end. Also protruding from the back on the fore part of the body are four erect, short, brush-like tufts of white or yellowish hairs. Along the back, interrupted by the tufts and tubercles is a broad, velvety, black stripe.

Pupa.— The pupa, which is enclosed in a very thin cocoon, is soft and fleshy, having a pale greenish or brownish color. The markings of the adult moth may be partly recognized before the insect emerges. The male pupa is slender with prominent antennal plates, while the female pupa is larger, more robust, and the antennal plates are not conspicuous.

Adult.— The male and female moths differ greatly. The male is an attractive moth, with prominent legs, large feathery antennæ, and slender body. It has normal wings, which are rounded in form and brown in color with delicate gray markings. The female bears no resemblance to the male. It is "wingless" and gray in color. The abdomen is sack-like while the legs and antennæ are slender.

LIFE HISTORY.

The insect lives through the winter in the egg and in this latitude the caterpillars hatch some time during the latter part of May. It takes twenty-five to thirty-one days for the caterpillars to complete their growth. The insect remains in the pupa stage from ten to fifteen days. At the end of this time the female emerges from the pupa and after mating, deposits her eggs upon the discarded cocoon.

According to Dr. E. P. Felt, there is normally only one brood of caterpillars a year in the latitude of Albany. Our studies of the insect during the past summer confirm these observations, as there has been no evidence of a second brood about Geneva or Lockport. In Boston and New York City there are two broods and farther south, about Washington, D. C., there may be three broods.

Some life history observations.— When attention was called to this species on June 13, 1908, the first three stages of the larva were recognized at this time feeding upon apples and pears. The earliest date for the finding of cocoons was June 27, when one was observed near Lockport. A male moth emerged July 9 and egg-masses were observed for the first time on July 12. In the early summer eggs, larvæ, pupæ and adults were frequently found on the same tree. Most of the cocoons were formed by July 15, but a few caterpillars were observed from time to time until August 21.

Habits of the caterpillar.— Upon hatching, the caterpillars begin to feed upon the underside of the leaves, at first eating only a portion of the leaf. As the caterpillar molts and increases in size, larger holes are made, and, when mature, the whole leaf is devoured except possibly the largest veins. The younger stages of the caterpillar will, if disturbed, suspend themselves by a strand of silk, and upon further jarring will usually drop to the ground. When the caterpillars are numerous on a tree, they are disposed, at the end of the feeding period, to migrate to considerable distances. The caterpillar will crawl down from the tree upon which it hatched and matured, and ascend the trunk of another tree in order to spin its cocoon.

Natural spread of the insect.— The spreading of the insect from one tree to another and from one locality to another depends very much upon the migratory habits of the caterpillar. In this way trees that have in the past been free from injury may become infested. The caterpillars are, when numerous, undoubtedly often carried from one place to another by dropping on passing vehicles or people. In addition, the insect may be transported in the egg stage, as the egg masses are often attached to nursey stock.

NATURAL ENEMIES OF THE TUSSOCK MOTH.

Birds.— The tussock moth has a large number of efficient natural enemies, which do much to decrease the numbers of

caterpillars and prevent even greater injury than is now accomplished. A number of birds are known to feed upon the larvæ, especially on the younger stages. The fact that our native birds are present in cities in comparatively small numbers has been assigned as a reason for the greater abundance of caterpillars in cities than in the rural districts where birds are more plentiful.

Insect parasites.— In addition to the birds the moth has a large number of parasitic enemies, including some very active species. During the past season, parasites have been numerous. Examinations of cocoons about Geneva indicated that 60 per ct. of them were parasitized, while in the vicinity of Lockport the parasitism of cocoons in some orchards reached 80 per ct. Mr. B. D. Van Buren reports that in some of the localities in Buffalo, where the caterpillars were very numerous and the trees had been stripped of their foliage, 95 per ct. of the cocoons were parasitized. In this latter instance only an occasional egg mass could be found, although the cocoons were distributed in considerable numbers over the trees. Of the parasitized cocoons examined at Lockport and Geneva, fully 95 per ct. were infested with *Pimpla inquisitor* and *P. conquisitor,* the former species being the more numerous. A few cocoons were found infested with larvæ from which a number of tachinid flies were bred. Through the courtesy of Dr. Howard, these were examined by Mr. C. H. T. Townsend and identified by him as *Tachina clisiocampae* Towns. and *Sisyropa* sp. nov.

MEASURES FOR THE CONTROL OF THE TUSSOCK MOTH.

IN ORCHARDS.

1. *Collecting egg-clusters.*—A severe outbreak of this pest in fruit orchards, such as occurred during the past spring in Niagara County, could be entirely prevented by destroying the eggs of the insect. These eggs are deposited in clusters and appear as a mass of white froth, about one-half inch wide and

an inch to an inch and a half long. The eggs are firmly held together by the tough material that gives the mass its frothy appearance, and most of the clusters are located in plain view on the trunks and branches of the trees, where they may be easily scraped off with a hoe or other sharp instrument and destroyed. In this work a search should be made for egg clusters that are attached to the smaller branches. These are often partly hidden by leaves that are attached to the cocoon on which the cluster has been deposited. The egg masses should be collected some time during the fall and winter or in the spring before the first of May. In the southern part of the State and on Long Island, where there are two broods of the insect, a summer collection of eggs should be made.

2. *Spraying with arsenicals.*— Next to destroying the eggs, the use of arsenical sprays is the most efficient means of preventing injury by this pest. More care in coating the undersides of the leaves than is usually observed in the regular applications of bordeaux mixture and poison that are made preceding and at blossoming time, would do much to prevent an outbreak of this and other leaf-feeding pests. However, if the caterpillars are not discovered until they have begun to eat into the fruit, it is advisable to use larger amounts of the poison than is customary in spraying for the codling moth. In making the application precaution should be taken to coat the fruit and both surfaces of the leaves with the spraying mixture.

3. *Jarring the trees.*— The foliage and fruit of small trees or even occasional branches of large trees that are being injured by the caterpillars may be saved from further loss by shaking. When the branch is jarred, the caterpillar suspends itself by a strand of silk, and will drop to the ground if the shaking be continued. A padded mallet or pole can be used to jar the branches, and the insects, as they drop, may be caught on a sheet or curculio catcher. This is a slow, tedious method of combating the pest, but by this means further injury to the fruit crop may often be prevented.

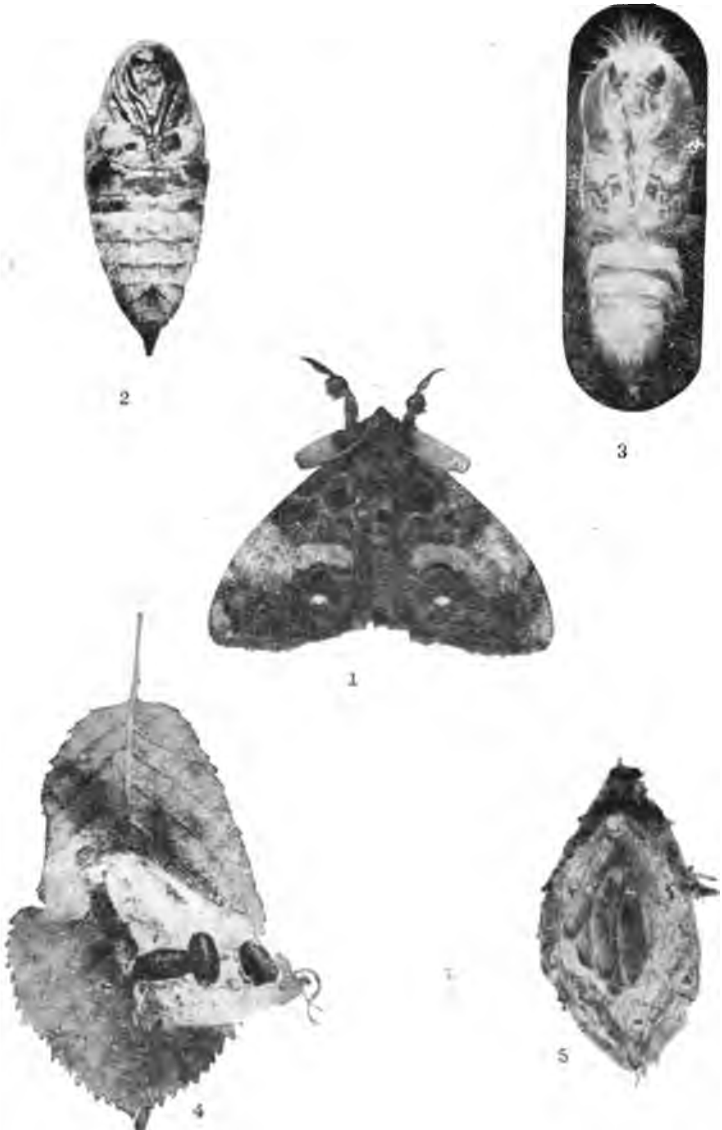

PLATE XXIV.— LIFE STAGES OF TUSSOCK MOTH: FIGS. 1 AND 3, ADULT MALE AND PUPA, ENLARGED; FIG. 2, FEMALE PUPA, ENLARGED; FIGS. 4 AND 5, PARASITIZED COCOONS.

4. *Banding the trees.*— In conjunction with collecting the egg masses or spraying, banding will serve to protect the trees from reinfestation by migrating caterpillars. This is often desirable when there are badly infested trees in the immediate vicinity. The band may be made of a strip of raw cotton or sticky fly paper. The cotton should be tightly fastened about the middle *so that it is loose above and below.* The barbed hairs of the caterpillar become entangled in the cotton fibres, and it is unable to pass over the band. In order to be effective, the bands should be renewed from time to time as they become soiled or matted by rain. In this latitude the bands should be employed during the months of June, July and August.

ON SHADE TREES.

The same measures that are recommended for the treatment of this pest in orchards are also applicable to the treatment of shade trees, only here more emphasis should be placed on the value of banding the trees and collecting the egg masses. Spraying shade trees is not practicable for the average property owner because the trees are usually of large size. Such operations require special machinery and men having considerable knowledge of spraying methods. Spraying of shade trees is not done to any great extent except where the work is directed by the municipal authorities. However, it is in the power of every resident to completely protect his trees by destroying the egg masses and banding the trees to prevent reinfestation by migrating caterpillars.

CONCENTRATED LIME-SULPHUR MIXTURES:*

P. J. PARROTT

SUMMARY.

During recent years commercial preparations of the lime-sulphur wash have been introduced into this State, and in several centers of fruit production they have been extensively used to combat certain injurious insects and plant diseases. Thorough spraying with these mixtures at effective strengths has generally given satisfactory results on the scale and blister-mite; and the experiences of many large orchardists indicate that the best commercial brands are efficient substitutes for the home-made wash for these pests.

Analyses of samples of commercial mixtures sold in the State during the spring of 1909 showed some brands to vary in the density of the clear solution and in the amount of sediment they contained. The range of density was from 26.8 to 33.9 degrees Beaumé, and the variation in sediment was from 0 to 19.42 per ct.

Compounders of certain brands have established a standard strength for their lime-sulphur solutions, which is guaranteed to the purchaser. These preparations consist of a clear reddish liquid, which is free from sediment and tests between 32 and 34 degrees Beaumé. Brands that show considerable variation in their chemical or physical composition should be avoided.

Field experiments to test the value of the sediment of a commercial lime-sulphur mixture in controlling the San José scale

*A reprint of Bulletin No. 320.

demonstrated that the insoluble portion possesses very weak, if any, insecticidal properties on this pest. The sulphur sprays derive their chief insecticidal value from the soluble lime-sulphur compounds. The addition of the sediment of a commercial or home-made lime-sulphur wash as extra material has apparently no detrimental influence on the effectiveness of the clear solution. The strength of the diluted preparation should be based on the clear solution.

On the basis of reasonable efficiency and cost, the strengths of effective mixtures for the San José scale, using a lime-sulphur solution testing 33 degrees B., range from one gallon of the concentrate diluted with eight gallons of water to one gallon of the solution diluted with eleven gallons of water. In orchards where the scale is not thoroughly controlled, the stronger mixtures are recommended. For spraying for the blister-mite, a dilution of one gallon of the concentrate to eleven gallons of water makes an effective spray.

Present evidence indicates that the common spraying arsenicals do not materially affect the value of lime-sulphur mixtures. In spraying for the scale or blister-mite, an arsenical in the usual amount for orchard treatment may apparently be safely added to a diluted sulphur solution for the purpose of controlling the bud-moth and casebearers, which are now very destructive in many apple orchards.

The second year's experiments with the home-made concentrated lime-sulphur wash gave satisfactory results on the scale and blister-mite. The different preparations showed some variation in the density of the solution and in the quantity of sediment, requiring the use of a hydrometer to obtain diluted mixtures of definite strength. This method of preparing a sulphur spray has several advantages, and should be tested by fruit growers owning suitable cooking outfits, to determine its applicability under their own conditions. The history of the commercial lime-sulphur mixtures indicates that the average fruit grower prefers to buy the prepared mixtures.

INTRODUCTION.

There is at the present time much demand for information along various phases of the subject of sulphur sprays. These demands the Station has attempted to meet: — (1) By a chemical study of the compounds formed in making a lime-sulphur wash; (2) by the determination of the composition of various commercial brands; and (3) by experiments, which are to serve as a basis for recommendations of the concentrated solutions. Some of the conclusions of the chemical investigations have been presented,[1] and it is reserved for this discussion to present especially some practical applications of the results of these efforts, that there may be a better understanding of the nature and uses of the concentrated preparations of the lime-sulphur wash for orchard treatment.

COMMERCIAL CONCENTRATED LIME-SULPHUR MIXTURES.

HISTORICAL.

The commercial lime-sulphur solutions were introduced in this State during 1907 and 1908, when two brands were tested experimentally in various communities, to determine principally their effectiveness for the scale and blister-mite, and for certain fruit diseases. The satisfactory results attending some of these tests were given widespread notice, which encouraged a much more extensive use of these mixtures during the past spring. The demand for the commercial brands prompted other companies to compete for the trade, so that there are now at least five companies which are selling their preparations to the fruit growers of this State. The mixtures were generally sold at from 17 to 20 cents a gallon according to the locality of the purchaser. In some communities, where competition was keen, the cost was as low as 15 cents a gallon. The sales for the spring of 1909 amounted to approximately 4,500 barrels.

[1] See Bulletin 319 of this Station by Dr. L. L. Van Slyke, C. C. Hedges and A. W. Bosworth. (Reprinted on pages 352–387 of this Report.) The analyses given in this article were kindly furnished by these authors.

In the use of these new sprays for the blister-mite, fruit growers generally have been very successful. In the operations against the scale, varying results have been reported. The failures for the most part have been largely due to attending circumstances rather than to any deficiencies in the leading brands. In the light of experimental tests and the successful operations of many orchardists it appears that the best commercial lime-sulphur solutions used at effective strengths are efficient substitutes for the home-made wash for these two pests. The history of these proprietary mixtures in the West indicates that in this State there will be in the future a more extensive employment of these preparations, largely because of their efficient properties and of the convenience in handling them.

NATURE OF THE MIXTURES.

The commercial mixtures, like the home-prepared wash, are derived from lime and sulphur. These ingredients, when used alone, dissolve only slightly in water, but when they are boiled together, they unite, forming a series of compounds which are very soluble. These make the lime-sulphur wash or spray which is employed as an insecticide. The commercial brands differ from the home-made wash principally in that they are in a highly concentrated state, which has made it feasible to prepare a sulphur wash as a commercial commodity, to be stored, shipped and sold for insecticidal purposes. The most concentrated of the leading commercial brands are approximately eight or more times as strong as the home-made mixtures. The best of these preparations also differ in appearance from the wash made by the fruit grower himself, in that the heavy sediment or mud has been excluded, either by settling or filtering. This process takes out the insoluble ingredients and leaves the solution a clear, sparkling, reddish or deep cherry color. The liquid contains the soluble lime-sulphur compounds, which give the wash its insecticidal value. Another important property of the more carefully prepared of the commercial brands, unlike the home-boiled wash, is their comparative freedom from

crystallization when cold, even in prolonged storage. This has been attained by using the minimum amount of lime necessary to combine with the sulphur, and by keeping the clear concentrate in tight containers.

The relative amounts of sulphur in solution in the common lime-sulphur wash and two commercial preparations, one being of low density and the other of high density, are as follows:

TABLE I.—SOLUBLE SULPHUR IN LIME-SULPHUR MIXTURES.

	Degrees Beaumé.	Sulphur in one barrel.	Total sulphur.	Sulphide sulphur.	Thiosulphate sulphur.	Lime (CaO).
		Lbs.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
[2]Common lime-sulphur wash.	6.6	15	3.50	2.40	1.10	3.00
Commercial concentrated lime-sulphur solution, low density	26.8	96	18.70	16.50	2.20	8.20
Commercial concentrated lime-sulphur solution, high density	34.5	135	26.50	25.60	0.90	10.90

VARIATIONS IN COMMERCIAL MIXTURES.

Density of clear solution.—Variations in the degree of concentration of the commercial lime-sulphur mixtures may occur with different barrels of the same brand. Some companies compounding these sprays have apparently not been able to produce a wash of definite strength or have failed to realize the importance of maintaining a uniform grade for their product. In the early history of concentrated-wash making, it was apparently a difficult matter to make the different boilings of uniformly high density, and frequently preparations from the same firm showed considerable variation in the amount of

[2] This wash was prepared after the common formula of lime 20 lbs., sulphur 15 lbs. and water 50 gals. It is probably a stronger mixture than is generally made.

sulphur in solution in their preparations. Analyses of the samples of the different brands sold in this State during the past year show that this variation may still occur, for the range in densities of the solutions that were examined was from 26.80° to 33.90° Beaumé. The approximate amount and value of sulphur in solution in preparations included in this range of densities are given in the accompanying table.

TABLE II.— APPROXIMATE AMOUNT AND VALUE OF SOLUBLE SULPHUR IN MIXTURES TESTING FROM 26° TO 34° B.

Degrees Beaumé.	Percentage of sulphur in solution.	Value[a] of sulphur.
	Per ct.	
26	19.76	$7.87
27	20.56	8.19
28	21.28	8.48
29	22.04	8.78
30	22.80	9.09
31	23.56	9.39
32	24.32	9.69
33	25.08	10.00

OCCURRENCE OF SEDIMENT.

In making a lime-sulphur wash, there is always more or less sediment or residue, which on settling largely accumulates in layers on the bottom of the cooking vessel. This is composed for the most part of undissolved lime and sulphur, of insoluble compounds derived from the lime and sulphur and of various impurities of the lime, principally magnesium. One of the striking differences among the brands sold in this State during the past year was in the relative freedom from sediment or sludge. Some preparations were entirely clear, the residue having been excluded, while preparations of another brand were apparently neither strained or filtered, and contained a varying amount of sediment. The variation of the different brands in this respect is shown in the accompanying table.

[a] Valuation is based on solution testing 33° B. and selling for $10.00 a barrel.

TABLE III.— SEDIMENT IN COMMERCIAL PREPARATIONS.

NAME OF BRAND.	Beaumé reading of clear solution.	Sulphur in solution in one barrel.	SEDIMENT.			
			Free sulphur.	Sulphur as sulphite.	Calcium, magnesium, etc.	Sediment in one barrel.
	Deg.	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	*Lbs.*
Grasselli	32.7	139	—	—	—	—
"	32.0	131	—	—	—	—
"	31.8	131	—	—	—	—
Niagara	30.4	124	—	—	—	—
"	34.5	130	6.8	15.9	28.4	74
"	31.1	106	5.9	16.7	29.9	110
"	31.4	119	0.9	16.0	29.0	45
Rex	31.2	129	—	—	—	—
"	33.0	138	—	—	—	—
"	31.2	129	—	—	—	—
Thomsen	26.8	96	—	—	—	—
"	33.9	139	—	—	—	—

These variations in the amount of soluble sulphur and sediment largely explain the conflicting results obtained by fruit growers in their spraying operations for the scale. The analyses also emphasize the importance of uniformity of composition, especially in its bearing on the question of the market value of the goods and in the matter of dilution to obtain preparations of constant strength. The more reliable compounders have realized the necessity of producing a uniform, high-grade product, and have established a standard strength for their preparations, which is guaranteed to the purchaser. This standardization of the various brands will presumably be generally adopted, as there would apparently be but a small demand for mixtures that show considerable variation in their chemical or physical composition.

THE INSECTICIDAL PROPERTIES OF THE SEDIMENT OF THE LIME-SULPHUR WASH.

Considerable interest was created throughout the leading centers of fruit production by the claim that sediment is a desirable ingredient of a concentrated mixture. Mixtures containing insoluble sediment or sludge were recommended and were reported as being sold for a higher price than the clear

solution of the same brand. While the value of the sediment was not definitely known, it has been supposed that the efficiency of lime-sulphur washes as insecticides is chiefly determined by the soluble lime-sulphur compounds, and that in comparison with these the insoluble sludge is a much less important constituent. To determine the relative effectiveness of the soluble and insoluble ingredients of the lime-sulphur wash on the San José scale was the aim of the following experiments.

EFFECTIVENESS OF SEDIMENT ON THE SAN JOSÉ SCALE.

The trees in these experiments were much infested with the San José scale. The sediment was taken from several barrels of a commercial brand, containing about fifteen per ct. of insoluble material, which was obtained by filtering. The filtrate was then repeatedly washed until tests showed no traces of soluble sulphur. This filtrate, when dried and ground, presented the appearance of a greyish powder. Chemical analyses showed that the sediment consisted largely of calcium sulphite, calcium sulphate, and free sulphur.

Series I.—In this first series several tests were made with the sediment, in the proportions of one gallon of the stiff paste, thinned with nine or eleven gallons of water. The mixtures were applied with a spray pump. The applications after drying left a light coating on the trees, which was of a bluish gray color. For purposes of comparison some treatments were also made with lime-sulphur solution testing 33° Beaumé at dilutions of one gallon to either nine or eleven gallons of water.

Results on scale.—Applications of the sediment of either dilution had no appreciable destructive effects on the scale. The production of the young at the beginning of the breeding season was apparently as abundant as that occurring on the untreated trees, and throughout the summer there was no appreciable difference in the amount of infestation of the checks and of the trees sprayed with the sediment. The treatment with the clear solution, diluted with nine parts of water, practically destroyed the scales, as only an occasional active larva was observed. The weaker preparation, containing one gallon

of the concentrate diluted with eleven gallons of water, while not so effective, greatly reduced the amount of breeding, and cleaned the bark of many of the older scales. The adhesiveness of the clear solution was noticeably superior to that of the sediment.

Series II.—This comprised a number of miscellaneous experiments, repeated at various intervals, with sediment from which the soluble sulphur compounds had been removed by decantation. This was applied at different consistencies by mixing with one or more volumes of water. For purposes of comparison many other trees, similarly infested with scale, were thickly painted with calcium sulphite, calcium sulphate, and lime paste. Some small trees growing in a greenhouse were given the same treatments to facilitate closer observations on the movements of the young scales.

Results on the scale.— The trees that were grown in the open field exposed to the usual conditions of weather were practically free of the heavy coating before the appearance of the lice, although the bark showed some discoloration by the treatments. Trees similarly painted with these materials but which were grown in a greenhouse, free from the influences of weather, retained their coatings intact for a long time after breeding commenced. None of the applications made to the trees growing in the open and subjected to normal weather conditions efficiently controlled the scale. The lime-sulphur sediment, calcium sulphite, calcium sulphate and lime wash, applied as a rather thick paint to form an appreciable crust on the bark, removed, on weathering off, some of the old scales, but in no instance did the treatments prevent considerable production of young scales.

Of the experiments in the greenhouse, the applications of these same materials, using them in the consistency of thin paint, had no important effect in reducing the numbers of young scales. The trees, however, which continued to be thickly coated with the application at the time of breeding, were generally exempt from new infestation. Large numbers of the mature females were able to project the posterior por-

tions of their bodies through the crust, but few young were born, and these were apparently unable to establish themselves.

Conclusion.—In the tests, conducted under ordinary field conditions, the insoluble sediment has shown very weak insecticidal properties. Thorough applications of it have never materially checked the breeding of the San José scale, and consequently have afforded very little, if any, protection to the trees. As has generally been believed, the experiments have shown very conclusively that, as regards this insect, the lime-sulphur wash derives its chief insecticidal value from the soluble lime-sulphur compounds. In purchasing preparations for scale treatment, the presence of sediment in appreciable quantities in a *commercial* lime-sulphur mixture is undesirable for two reasons,—(1) because of its cost, and (2) because of the danger of uncertain results in spraying, through the substitution of insoluble materials for the clear solution.

Judging from the results of these experiments it would appear that there is no objection to adding the sediment, or sludge, of a commercial or a home-made lime-sulphur wash to a clear solution as extra material, to give body to the preparations. The actual value derived from their addition is not known. A heavy coating on the trees serves to indicate the thoroughness of the spraying, and according to its thickness and adhesive properties exerts certain smothering effects on such sluggish insects as scales and lice. On weathering off, the flakes of the insoluble materials also carry with them some of the protective coverings of the scales, and perhaps a few of the insects themselves.

STRENGTHS OF EFFECTIVE MIXTURES FOR SCALE AND BLISTER-MITE.

In the use of the commercial lime-sulphur solutions there has been quite a little uncertainty as to the range of dilution with water, to obtain mixtures of suitable killing properties. The proportions that have usually been recommended for dormant treatment in advertising circulars would appear, on the basis on the sulphur content, to make a weaker spray than the

ordinary home-made mixture as it is used in this State for the treatment of the San José scale. To determine the strengths of efficient mixtures, experiments were made with commercial brands at various dilutions for the treatment of the scale and leaf blister-mite.

EXPERIMENTS WITH CONCENTRATED SOLUTIONS ON THE SCALE.

The concentrated lime-sulphur wash used in these experiments tested 33° Beaumé and was free from sediment. The range of dilution was from one gallon of the clear solution with four gallons of water, to one gallon of the concentrate with fifteen gallons of water. Tests were made once in 1908 and were repeated in three different plats during 1909. The trees were of the same age and variety, and were generally well infested with the scale.

Results on scale and discussion.—As compared with untreated trees, all of the applications at the range of dilution given showed improvement in the conditions of the trees with respect to the scale. As was to be expected, the stronger mixtures, broadly speaking, were more efficient and gave uniformly better results than the weaker preparations. However, the experiments did not indicate as decisively as was desired the exact dilution, which, from the standpoints of reasonable efficiency and cost, would make a satisfactory spraying mixture for average orchard conditions. For practical use, the strengths of effective mixtures seem to range from one gallon of the concentrate diluted with eight gallons of water, to a dilution as weak as one gallon of the solution to eleven gallons of water. Until there is more evidence by the fruit growers themselves, showing the range of safe dilution for commercial mixtures under the usual orchard conditions, it appears from these results that it would not be safe to take chances with as weak mixtures as have been advised. For spraying for the scale, especially if abundant, it is recommended that a lime-sulphur solution, testing 33° Beaumé, be diluted in the proportions of one gallon to either eight or nine gallons of water. Brands of less concentration should be diluted with proportionately less amount of water. In orchards that are regularly

sprayed and in which the scale is well under control, it is possible that somewhat weaker preparations than those advised may be safely employed, which can be more satisfactorily determined by the fruit grower himself from his own experience.

EXPERIMENTS WITH CONCENTRATED SOLUTION OF BLISTER-MITE.

The experiments were made on Greenings, about forty years of age and for several years considerably infested with the leaf blister-mite. The concentrated solution used in these tests was clear, and registered 33° B. The range of dilution of the applications was from one gallon of the solution with eight gallons of water, to one gallon of the concentrate with fifteen gallons of water. Applications were made during November of 1908 and during April of 1909. In some of the preparations lime was used, to determine the value of its addition to a lime sulphur-solution for the treatment of the mite.

Results on mite and discussion.— All preparations of the lime-sulphur wash, at the dilutions mentioned, completely controlled the blister-mite. The addition of lime paste had no appreciable influence on the effectiveness of the mixture. From the results of these experiments, a preparation comprising one gallon of lime-sulphur solution, testing 33° B. and diluted with eleven gallons of water is an efficient spray for blister-mite, and this strength is advised for the treatment of orchards infested with this pest, because of its reasonable cost, and its probable greater effectiveness for other parasites than more dilute preparations. As is indicated by the results of the tests, a weaker mixture than is advised could undoubtedly be safely used to control the blister-mite alone.

SPRAYING POISONS IN LIME-SULPHUR SOLUTIONS.

Present studies indicate that arsenical poisons may be combined with lime-sulphur solutions. The available poisons are arsenate of lead*, and arsenite† of lime. Fruit growers who are spraying for blister-mite may apparently safely combine the

* C. E. Bradley. *Jour. Indus. and Eng. Chem.* 1, 8: 606.
† J. P. Stewart. Penn. Sta. Bul. 92.

usual amount of an arsenical poison with a diluted sulphur solution for the purpose of controlling also the bud moth and case-bearer, which are now very destructive in many orchards. The arsenite of lime* should be prepared as follows:

White arsenic	2 lbs.
Sal soda crystals	2 lbs.
Water	1 to 1½ gal.

Boil until entirely dissolved, which requires about fifteen minutes. Use this solution to slake three or four pounds of good stone lime. If this slaking is properly done, the arsenic will be combined very effectively, and the arsenite of lime thus formed will retain its strength indefinitely. When ready for use, add water to the product to bring the total up to two gallons, and stir thoroughly. Two pints of the well-stirred, uniform mixture will then evidently contain one-eighth of the original materials or one-fourth pound of white arsenic, in the form of arsenite of lime, which is equal to one-half pound of paris green. This amount is ample for 50 gallons of diluted spray and it may be added immediately after dilution.

THE HYDROMETER AND ITS USES.

To obtain mixtures of definite strength, the lime-sulphur solutions should be diluted according to their degree of concentration. The hydrometer is used for this purpose. It is a glass instrument, consisting of a weighted bulb with a long stem, which determines the weight or density of liquids. Its general appearance is indicated in Fig. 11. On the stem of the instrument there is a graduated scale, which should be read at the general surface of the liquid in which it is supported. Hydrometers are of two kinds,— the Beaumé and the Specific Gravity, which differ in the standards of measurements on which the graduated scales are based. There are instruments which have both measurements. Readings on the former are given in numerals expressed as degrees, while those on the latter are made in decimals. Instruments with a range of 0 to

* J. P. Stewart. Penn. Sta. Bul. 92.

36 degrees Beaumé or 1.000 to 1.330 Specific Gravity are recommended. Hydrometers do not detect impurities in lime-sulphur solutions; these can be determined only by chemical analysis.

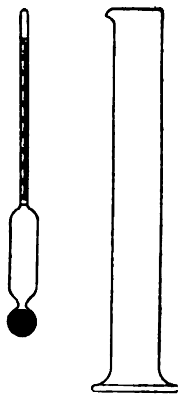

FIG. 11.

Hydrometers can be purchased from Bausch & Lomb Optical Co., Rochester, N. Y., Eimer and Amend, New York City, Whitall Tatum Co., New York City, and wholesale dealers in druggists' supplies. A convenient and useful outfit may be obtained from the Bausch & Lomb Co. This consists of two hydrometers, one to determine the density of the concentrated solutions, preparatory to dilution, one to gauge the strength of the diluted mixture, and a glass jar, to contain the liquids for the tests. Fig. 11. By the use of the two instruments the divisions of the graduated scale are made larger, which enables the readings to be made with greater ease and accuracy.

DIRECTIONS FOR DILUTING LIME-SULPHUR SOLUTIONS.

BRANDS OF STANDARD STRENGTH.

If the brand of concentrated lime-sulphur solution is of standard strength, the question of dilution is a simple matter. Such a preparation should be clear, free from sediment, and should test uniformly between 32 and 34 degrees Beaumé,

which can be verified by the hydrometer. For spraying for the San José scale and the leaf blister-mite, dilute as follows:

For San José scale, use one gallon of the concentrated solution with eight or nine gallons of water, employing the former strength when considerable infestation exists. The stronger mixture should give a reading on the hydrometer of 4.4 or 4.5 degrees B. or about 1.030 Sp. G.

For blister-mite use one gallon of the concentrated solution with eleven gallons of water. The diluted mixture should test on the hydrometer about 3.5 B. or 1.026 Sp. G.

BRANDS OF VARYING STRENGTH.

With mixtures of varying densities determine the strength of the clear solution by the hydrometer, and mark the reading on the container. In using this stock solution for strong mixtures for the scale or for the blister-mite, dilute in the proportions given in the accompanying table.

TABLE IV.— TABLE FOR DILUTING SOLUTIONS OF VARYING CONCENTRATION.

Reading on hydrometer.		Amount of dilution. Number of gallons of water to one gallon of lime-sulphur solution.	
Degrees Beaumé.	Specific gravity.	For San José scale.	For blister-mite.
35	1.3181	1 to 9	1 to 12
34	1.3063	1 " 8½	1 " 11½
33	1.2946	1 " 8	1 " 11
32	1.2831	1 " 7¾	1 " 10½
31	1.2719	1 " 7½	1 " 10
30	1.2608	1 " 7	1 " 9½
29	1.2500	1 " 6¾	1 " 9
28	1.2393	1 " 6½	1 " 8¾
27	1.2288	1 " 6	1 " 8¼
26	1.2184	1 " 5¾	1 " 7¾
25	1.2083	1 " 5½	1 " 7½
24	1.1983	1 " 5¼	1 " 7
23	1.1885	1 " 4¾	1 " 6¾
22	1.1788	1 " 4½	1 " 6¼
21	1.1693	1 " 4¼	1 " 5¾
20	1.1600	1 " 4	1 " 5½
19	1.1507	1 " 3¾	1 " 5
18	1.1417	1 " 3½	1 " 4¾
17	1.1328	1 " 3	1 " 4½
16	1.1240	1 " 2¾	1 " 4
15	1.1153	1 " 2½	1 " 3¾

THE HOME-MADE CONCENTRATED LIME-SULPHUR WASH.

In Bulletin 306 of this Station, the attention of our fruit growers was called to the formula for a home-made concentrated lime-sulphur wash. The steps required in mixing the ingredients and in cooking the wash are similar to those in preparing the sulphur wash by the common method. In the treatment of the Station orchards and in several rather extensive co-operative tests, many barrels of mixture by the new formula were used, and whenever the preparations were applied at efficient strengths, as indicated by hydrometer tests, satisfactory results were obtained on the scale and blister-mite. It is a convenient method of preparing a lime-sulphur wash and could be employed for several useful purposes by fruit growers who have had experience in making their own sulphur sprays. It should especially meet the needs of farmers owning detached orchards at considerable distances from the cooking plants. The advantages of this mixture are:—It has no coarse sediment to clog nozzels and to cause the rapid wearing out of the packing, lining and other parts of the pump, and it may be prepared in concentrated solutions to be diluted as needed. For the present we advise fruit growers, making their own sulphur sprays for the treatment of the scale, to continue to use the common boiled wash for the larger portion of their operations and to employ the concentrated solution experimentally until its effectiveness for this pest under their own conditions is thoroughly established. The history of the commercial concentrated lime-sulphur solutions indicates that the average fruit grower prefers to use the prepared mixtures.

FORMULA.*

Lump lime	60 lbs.
Sulphur	125 "
Water	50 gals.

* Some changes are being made as regards to the proportions of lime and sulphur but we give this formula as it is the one that we have used in our tests.

MATERIALS.

The forms of sulphur which are adapted for concentrated solutions are flowers of sulphur, and light and heavy sulphur flour. These can be obtained from the wholesale druggist handling spraying supplies. The lime should be fresh lump lime, free from dirt and grit. It should test not less than 90 per ct. calcium and should contain not more than five per ct. of magnesium oxide.

COOKING THE WASH.

Slake the lime, which should be of a consistency of thin paste, and add the sulphur. Stir the materials thoroughly during the cooking process in order to break up the coarse lumps of sulphur. Boil the wash vigorously for one hour, in which time the sulphur should be completely dissolved. In starting the wash to cook, a sufficient quantity of water should be used to provide for shrinkage so that there will be fifty gallons of mixture at the completion of the boiling. With kettles an allowance of ten or fifteen gallons may be required while an outfit using direct steam will usually not need additional water. A few boilings should indicate the quantities of water needed to make approximately the amount of concentrate given in the formula. In using barrels or kettles of fifty gallons capacity, it is advisable to make one-half of the mixture provided by the formula, to avoid losses by the boiling over of the materials.

BARRELING THE CONCENTRATED SOLUTION.

If the concentrate is not for immediate use, it should be stored in tight containers. After boiling is completed, strain the mixture into a barrel, which should then be corked. A sample of the clear solution should be tested by the hydrometer, and the reading marked on the container, to indicate the required dilution for future use. The coarse particles of sulphur in the residue may be cooked up in later boilings.

STORAGE OF LIME-SULPHUR SOLUTION.

Lime-sulphur solutions may safely be stored if they are not subjected to very low temperatures. In general one should avoid prolonged storage and prepare the mixtures just preced-

ing or at the time of the spraying operations, when dangers of freezing are avoided. According to Stewart* a solution of 32.1 Beaumé (1.28 Sp. G.) does not freeze above 5° F. and shows no deterioration by freezing. Mixtures of lesser density will freeze at higher temperatures. Preparations that are to be used within a few days may be kept if desired in open vats or barrels. In this case, transfer the hot concentrate to the proper container, and cover the surface of the liquid with a thin film of mineral oil.

DIFFICULTIES IN MAKING CONCENTRATED SOLUTIONS.

The principal difficulties to be met in making a concentrated lime-sulphur solution are to obtain preparations of high densities and to avoid large amounts of sediment. In the Station tests,† the different boilings varied in degrees of concentration and when lime containing magnesium was used, there was always quite a quantity of sediment. In our own experience we found it impracticable to attempt to obtain solutions of definite strength. As soon as the cooking was done, the preparation was immediately applied or barreled. For use, the clear solution was tested with a hydrometer, and the preparation was diluted with water according to its density. It is impossible to avoid a certain amount of sediment but to reduce the

* Penn. Sta. Bul. 92.

† The variation in the density and in the amount of mixture in different boilings is illustrated by the following examples. One-half of the materials required by the formula were used. The lime was 91 per cent. calcium and five more pounds were added because of the impurities. The temperature of the mixtures was 70° F. and apparently all the sediment had settled when tests by hydrometer were made.

(1) Cooked by kettle;—extra water 22 gals. Amount of concentrate 31½ gals. Clear solution tested 26½° B.

(2) Cooked by kettle;—extra water 16 gals. Amount of concentrate 22½ gals. Clear solution tested 33° B.

(3) Cooked by steam coil;—extra water 3 gals. Amount of concentrate 27 gals. Clear solution tested 27½° B.

(4) Cooked by steam coil;—no extra water. Amount of concentrate 25 gals. Clear solution tested 28° B.

(5) Cooked by direct steam;—no extra water. Amount of concentrate 24 gals. Clear solution tested 32° B.

quantity one should employ high-grade lime, practically free from magnesium compounds. By using lime testing at least 90 per ct. calcium, and with thorough stirring and vigorous cooking we have been able to make concentrated solutions, which ranged in density from 25° to 33° Beaumé. There was practically no coarse sediment in any of the boilings, and usually all of the mixtures would pass through the ordinary strainer. It is not advisable to separate the clear liquid from the insoluble materials because of the time required by this operation and the loss of efficient liquids.

REPORT

OF THE

Horticultural Department.

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SOD

TILLAGE

SIZE AND COLOR OF SOD AND TILLAGE APPLES

REPORT OF THE HORTICULTURAL DEPARTMENT.

A COMPARISON OF TILLAGE AND SOD MULCH IN AN APPLE ORCHARD.*

U. P. HEDRICK.

SUMMARY.

In an attempt to answer the question as to whether the apple thrives better under tillage or in sod, the New York Agricultural Experiment Station is conducting two experiments. This bulletin is a preliminary report on one of these experiments.

The problem on hand is to determine what the comparative effects of tillage and sod are on the apple. The method of tillage chosen was to plow in the spring, cultivate until late July, and follow with a cover-crop. The sod method chosen was that known as the sod-mulch, or Hitchings, method in which the grass is cut as a mulch.

The experiment under consideration was begun in 1903 in the orchard of Mr. W. D. Auchter, near Rochester, New York. This orchard consists of nine and one-half acres of Baldwin trees set in 1877, forty feet apart each way. The number of trees in the sod plat is 118; in the tilled plat, 121.

In topography the Auchter orchard is slightly rolling. The soil is a fertile Dunkirk loam to a depth of ten inches, underlain by a sandy subsoil. Variations in soil are few and slight.

The trees in the two plats received identical care in all orchard operations excepting soil treatment. The grass in the sod plat was cut twice in three of the five years, in the other two but once. The tilled land was plowed each spring and cultivated from four to seven times.

The relative merits of the two treatments were gauged by all important characters of fruit and tree. Statements of results follow:

* A reprint of Bulletin No. 314.

The average yield on the sod plat for the five years was 72.9 barrels per acre; for the tilled plat, 109.2 barrels; difference in favor of tilled plat, 36.3 barrels.

Estimates made at blooming and fruiting time showed a far greater number of fruits on the tilled trees. Actual count showed 434 apples per barrel on the sod land weighing 5.01 ounces each and 309 apples per barrel on the tilled plat weighing 7.04 ounces each.

The fruit from the sod-mulch plat is much more highly colored than that from the tilled plat.

The fruit on the sod-mulch plat matures from one to three weeks earlier than that on the tilled plat.

In common storage, fruit from the tilled plat keeps four weeks longer than that from the sod plat. In cold storage, the keeping quality of the two fruits is the same.

The tilled fruit is decidedly better in quality, being crisper, more juicy and of better flavor.

The advantage of tillage over the sod-mulch in the matter of uniformity of trees and crops is marked. The trees in sod showed abnormalities in foliage, branches, roots and particularly in fruit-bearing and in fruit characters.

The average gain in diameter of trunk for the trees in sod for the five years was 1.1 inches; for the trees under tillage 2.1 inches; gain in favor of tillage, 1 inch.

The dark, rich green color of the foliage of the tilled trees indicated that the tilled trees were in the best of health. On the other hand the yellow color of the leaves of the sod trees told at once that something was amiss.

It needed only a glance in the orchard to see that the leaves of the tilled trees were much larger and much more numerous and that therefore the total leaf area was much greater.

Leaves from sodded trees and the same number (2,400) from tilled trees were weighed and gave 8.7 grams as the average weight per leaf for the sodded trees and 11.5 grams for the tilled trees.

The leaves of the tilled trees came out three or four days earlier and remained on the trees a week or ten days later than on the sodded trees.

The average annual growth of branches for the sodded trees was 1.9 inches; for the tilled trees 4.4 inches. The average number of laterals per branch on the sodded trees was 3.4; on the tilled trees 6.7.

During the dormant season there was a striking difference in the appearance of the new wood in the two plats. The new wood on the tilled trees was plumper and brighter in color indicating better health.

The amount of dead wood in the sod-mulch trees was much greater than in the tilled trees.

The roots of the trees in the sod-mulch plat came to the very surface of the ground. How much these trees suffered by the destruction of roots in the heat and drought of summer or the cold of winter cannot be said. In the tilled land the roots were found in greatest abundance at a depth of from three to ten inches.

The circumference of the root systems in the tilled trees is approximately circular, but the circumference of the roots of the trees in sod is very irregular, indicating a reaching out of a part of the roots in response to a demand for more moisture, food, or air or to escape some evil effect of the grass roots.

A fair way of comparing the quantity of the living roots of the trees in the two plats could not be found.

The trees in the outside rows of the sod plat, where the roots could penetrate into the tilled land, without exception showed better health and greater productivity than the trees in the inner rows.

The average cost per acre for the two methods of management, not including harvesting, was $17.92 for the sod; and $24.47 for tillage giving a difference of $6.55 in favor of the sod. The average net income per acre for the sod plat was $71.52; for the tilled plat $110.43, a difference of $38.91 in favor of tillage, an increase of 54 per ct. for tillage over the sod-mulch method of management.

Tillage seems to be better than sod for the apple for the following reasons:

The results of 120 moisture determinations in the Auchter orchard show that the differences in tree growth and crop in the

two plats of this experiment are mainly due to differences in moisture, the tilled plat having most moisture.

As a consequence of the reduced water supply in the sod plat, there is a reduced food supply; for it is only through the medium of free water that plants can take in food. Analyses show that the differences between the actual amounts of plant food in the two plats are very small.

Analyses show that there is more humus in the tilled plat than in the sod plat, contradicting the oft made assertion that the tillage method of managing an orchard "burns out the humus."

At a depth of six inches, the tilled soil is 1.1 degrees warmer in the morning and 1.7 degrees at night, than the sod land; at twelve inches the tilled soil is 2.3 degrees warmer in the morning and 1.8 degrees in the evening.

We are justified, without the presentation of specific data, in saying that a tilled soil is better aerated than sodded land.

Soil investigators are well agreed that beneficial micro-organisms are found in greater numbers in a cultivated soil than in other soils.

The following application of the results of this experiment may be made:

Nearly all the plants which minister to the needs of man are improved by tillage; the apple does not seem to be an exception.

Results as positive as in this experiment can be made very comprehensive; they should apply to all varieties of apples and to nearly all soils and locations.

The experiment does not show that apples cannot be grown in sod; it suggests, however, that apples thrive in sod, not because of the sod, but in spite of it.

While moisture is by no means the only factor to be considered in the controversy over the sod and tillage methods of managements, it appears to be the chief one.

There is nothing in this experiment to indicate that trees will become adapted to grass. The sodded trees began to show ill-effects the first year the orchard was laid down to grass and each succeeding year has seen greater injury.

INTRODUCTION.

There has long been a controversy as to whether the apple thrives better under tillage or in sod. In an attempt to answer this question the New York Agricultural Experiment Station is conducting two experiments. This bulletin is a preliminary report on one of these investigations, the other not having been carried far enough to warrant a report. The first task at hand is to define terms, show the need of the investigation, and set the limits of the experiment.

TERMS DEFINED.

To *till* is to plow, harrow, cultivate or hoe; to turn, stir or loosen the soil about plants. The definition is clear and it is not necessary that it be amplified. Neither is it necessary to describe the operations, which singly or taken together, constitute tillage. They are known of all men, for they have been practiced since the beginning of agriculture and are now the chief tasks of all civilized peoples.

Fruit growers have found the cover crop so valuable an adjunct to tillage that it is now recognized as an indispensable part of the tillage method of managing an orchard. When tillage is spoken of in connection with orchard management it is understood that a cover crop or green manuring crop is used with it.

Sod is surface soil held together by the matted roots of living grass. Since any of the several grasses which grow in New York hold soil together, sod is variable in its constituency. Sods formed by single grasses are rare; they are usually composed of orchard or blue grass with greater or less quantities of ox-eye daisy, mullein, fleabane, the plantains, sorrels, docks, wild carrot or other weeds. Sods vary more or less in the amount of their vegetation. In some orchards they produce a very good hay crop and in others the turf-making

plants are so sparse in numbers and so scant in growth as scarcely to cover the ground. Because of the differences noted the sods in any two orchards are unlike—a fact that must be kept in mind in applying the results of this experiment.

The treatment of the sod in the orchards of this State varies greatly. Some orchardists remove the growth of grass as hay; others cut it as a mulch for the ground; still others supplement the natural growth of the land with additions of manure, straw or other organic matter to increase the amount of mulch. The great majority of the men in New York who grow apples in sod, however, pasture their orchards with sheep, pigs or cattle.

INVESTIGATION OF METHODS OF ORCHARD MANAGEMENT NECESSARY.

The tillage and the sod methods of managing orchards are so radically different that they cannot be equally good. One or the other is wrong in principle, except possibly in the rare exceptions which only go to prove the rule. Since tillage and sod culture are both largely practiced in New York, fruit growers should know their comparative merits that they may have assurance as to whether their practice is right or wrong. Then, too, there has been much talk in the State and country, pro and con, as to methods of orchard management without definite knowledge. In the discussion which has been going on, men for most part have been citing particular orchards,—isolated cases,—and not principles. It seems necessary to establish by means of experimental evidence, principles that will apply to orchards in general. Lastly, the men who deny the value of tillage for the apple are going counter to the established theories of agriculture; all admit that farm crops, vegetables, flowers, small fruits, vine fruits, and all tree fruits excepting the apple, and possibly the pear, thrive best under tillage. If the apple differs from other cultivated plants in this respect, the phenonemon is most interesting and well worthy investigation.

THE SOIL CONDITIONS OF NEW YORK APPLE ORCHARDS.

It is necessary to know something of the orchard soils of the State if application is to be made of results obtained on the particular soil in which this experiment has been carried on. As a preliminary to this report, therefore, questions were sent to the 2,000 members of the Western New York Horticultural Society and the New York State Fruit Growers' Association to obtain a general idea of the soil and the lay of the land of the orchards in New York. The following are summaries of the replies:

Of the 2,000 men addressed, 695 replied, representing 8,947 acres of apples. Of the men who sent answers, 194 were growing apples on clay loams; 173 on sandy loams; 151 on gravelly loams, and 77 on loams. The depth of top soil in 333 orchards was from 6 to 12 inches; 84, from 12 to 18 inches; 55, from 18 to 24 inches; 32, from 24 to 36 inches; 12, from 36 to 48 inches, while 12 soils were still deeper. The subsoils range as follows: Clay, 354; hardpan, 131; sand, 54; gravel, 33; and rock in 13 orchards. The land in 310 cases was level or nearly so; in 318, rolling, and in 55 hilly.

ORCHARD MANAGEMENT IN NEW YORK.

It is essential for the application of the results of an investigation of this kind to know what methods of orchard management are practiced in the region in which the results are to be applied. Questions were sent to the persons noted in the preceding paragraph and answers came as follows: 395 orchards are in sod; 370 are cultivated yearly; 33 are cultivated every other year; while 9 are cultivated at intervals of from two to five years.

Of those who cultivate, 277 plow yearly in the spring; 49 in fall or spring; 34 in the fall; while 9 plow two or more times during a season; 16 cultivate yearly but do not plow; 48 cultivate yearly but plow only once in from one to five years; 312 cultivate only until midseason while 11 till throughout the season. As to number of times, 14 culti-

vate one or two times; 92, three or four times; 69, five or six times; 29, seven or eight times; 6, nine or ten times; while one man tills twelve, two fourteen and two other enthusiasts fifteen times. Of the 370 men who cultivate, 224 use cover crops yearly; 132 use them only occasionally or not at all but plow under early green manuring crops or stable manure.

Of the men who have their orchards in sod, 324 pasture the land more or less. Of these 89 keep sheep alone in the orchard; 98, hogs; 30, cows; 62, hogs and sheep; while 45 use some combination of hogs, sheep, cows and horses. Of the 71 men who have sodded orchards but do not pasture them, 65 take either a yearly or an occasional crop of hay from the orchard. Of the orchards in sod 122 are given fall and winter dressings of stable manure; on 39 the practice is to cut the grass as mulch; on 24 stable manure, straw, cornstalks or other organic matter is used as a regular summer mulch; on 52 no mulch is applied.

Of the total number who replied, 569 growers say they use stable manure or commercial fertilizers in their orchards; 54 do not use fertilizers.

From the expressions made by the correspondents in this survey it is certain that the tendency in New York among apple growers is strongly toward tillage. Many of those who grow apples in sod express the conviction that the trees would do better under tillage but because of particular conditions they feel that they must keep their orchards in sod. Thus the statement was many times made that time could not be found to till, spray and take care of field or garden crops. Others were forced to keep the orchard in sod for the sake of the pasturage. A few, but they were so few as to be a negligible quantity, did not till because their land was so hilly or rocky that it could not be tilled. There were many cases in which the orchardist believed that his trees grew better in sod than under tillage. A careful study was made of these cases; few of them were in the commercial apple belts of either eastern or western New York where high cultivation is the rule. Many of the advocates of sod had deep soils, or soils retentive

of moisture such as are found in the numerous river valleys of the State. Most of the men who till had tried sod at one time or another; few of the men who favored sod had tried tillage; none had tried tillage and sod side by side for comparative results.

THE CHOICE OF A METHOD OF SOD CULTURE.

From the above considerations it is apparent that there is a great diversity of conditions and methods from which to choose for an experiment of this kind. In making a choice the aim was to select that set of conditions which would show whether tillage or sod is fundamentally better. Tillage versus the sod-mulch method, or the Hitchings' method, was selected as being most suitable. It was deemed impossible to conduct a fair experiment between tillage and sod pastured with farm animals because the trees in the sod receive an unknown quantity of fertilizer from the animals which cannot be given in similar amounts and in similar manner to the tilled trees. A method in which additions of organic matter other than that grown on the land was not chosen because it is wholly impracticable in this State to mulch orchards with straw or other vegetation—it is impossible to obtain the material for any considerable portion of the orchard area of New York. Beside, under the name of the "Hitchings' method" the sod-mulch is being more widely recommended for this region than is any other method.

THE PROBLEM IN HAND.

What are the comparative effects of tillage and sod on the apple tree? The problem in hand is stated precisely in the above sentence. As average and normal conditions in all respects have been selected for the investigation, it follows that the more nearly average and normal a man's orchard is the more applicable the results of this investigation. There are abnormal conditions, as steep hillsides, very wet, or very sandy, or very rocky land, under which trees will grow but in which

tillage is impossible. These are the exception, not the rule, and the results obtained in the Auchter orchard may not apply to them.

The question of individual expediency must be wholly eliminated in applying the results of this investigation. It may be profitable for a dairyman or a general farmer not competing with commercial fruit growers to pasture his orchard, or for lack of time neglect tilling it, even though it is not best for his trees. In a small home plantation sod makes the orchard a place of greater convenience for farm and family than does tillage. But these are matters of expediency, not of orchard practice.

PREVIOUS INVESTIGATIONS.

Much has been written on tillage and sod for the apple but the two methods have rarely been tried side by side for comparative results. Out of a great number of reports and discussions of the subject, only the following seem entitled to be called investigations:

THE WOBURN EXPERIMENT.

At the Woburn Experimental Fruit Farm, Ridgemont, England, experiments with trees in sod and under tillage have been carried on for the past thirteen years and have been reported upon from time to time by the experimenters.[1] The Third Report of the Woburn Farm is a treatise on The Effect of Grass on the Apple Tree in which the methods employed, the results obtained and the causes of the effects of grass on trees are very fully discussed. The conclusions of the Woburn Farm investigators as to effects are as follows:[2]

"As to the general effect produced by grass on young apple trees, the results of the last few years have brought forward nothing which can in any way modify our previous conclusions as to the intensely deleterious nature of this effect, and

[1] First, Second, Third and Fifth Reports of the Woburn Experimental Fruit Farm.

[2] Third Report of the Woburn Experimental Fruit Farm, 1903:4.

we can only repeat, that no ordinary form of ill-treatment—including, even, the combination of bad planting, growth of weeds, and total neglect—is so harmful to the trees as growing grass round them; indeed, the 'neglected' trees in plot 44, which up to 1900 showed only a slight advantage over the grass-grown trees, are now decidedly superior to them, both in size and vigor, whilst in the similarly 'neglected' plots of standards, the trees are but little less vigorous than the normal ones."

The authors state that their investigation leads them to believe that water supply, food supply, and air supply are not the principal causes of the deleterious effects of the grass on the trees.[3] Soil temperature is discussed and dismissed as not being a prime factor. The chief hypothesis set forth in this report as to the cause of the evil effect of grass on the apple is that a toxin is excreted by the grass roots. The statement in this regard is as follows:[4] "Direct experiments seem to negative the possibility of explaining the action of grass on apple trees in the various ways which we have discussed above, water, food and air supply, and lead us to a conclusion, which has also gradually been forced upon us by the appearance itself of the trees throughout the years that they have been under observation, namely, that this action of grass is not merely a question of starvation in any form, nor of any simple modification of the ordinary conditions under which a tree can thrive, but that the grass has some actively malignant effect on the tree, some action on it akin to that of direct poisoning."

INVESTIGATION AT THE OHIO AGRICULTURAL EXPERIMENT STATION.

In an experiment conducted at the Ohio Experiment Station by W. J. Green and F. H. Ballou[5] the investigators leave the inference that the apple thrives better under a sod and mulch method of management than under tillage and cover crops. The results obtained by the Ohio Station are as follows:

[3] Third Report of the Woburn Experimental Fruit Farm, 1903:23.
[4] Third Report of the Woburn Experimental Fruit Farm, 1903:47.
[5] Ohio Sta. Bul. 171., March, 1906.

"COMPARISON OF TREE GIRTHS IN DIFFERENT CULTURE PLOTS.*
Measurement taken twelve inches above ground.

Average girth of trees in cover-crop plot (No. 1)................	9.71 in.
Average girth of trees in sod-mulch plot (No. 4)................	10.56 in.

"COMPARISON OF FIRST YIELD OF FRUIT FROM DIFFERENT CULTURE PLOTS.

Variety	Method of culture	Number of apples	Total weight of apples	Average weight of each specimen
Jonathan..........	Cover-crop....	70	21 lbs.	4.8 ozs.
"	Sod-mulch....	172	55½ lbs.	5.16 ozs.
Grimes............	Cover-crop....	59	23 lbs.	6.23 ozs.
"	Sod-mulch....	82	30½ lbs.	5.95 ozs."

* Data given in bulletin as to "sod-culture" are omitted, they having no bearing on the subject in hand.

Beside this table there are photographs showing that the trees in sod are thriftier than those under tillage. In studies made of the root systems of the trees, the investigators do not make plain which method is most conducive to root development. The effect of the two treatments on the fruit itself, as to color, quality, maturity, keeping qualities and size, are not given,—an unfortunate omission, for the value of a crop of apples depends much upon the character of the fruit. So, too, important characters of the trees are not discussed. The size, amount, and color of the foliage of the trees indicate its welfare; yet the character of the foliage of the trees in the two plots is not discussed in this bulletin. There are no statements regarding uniformity of trees or crop. Were the trees uniform in growth and were the 129 apples from the tilled plot produced on one tree or distributed over the 40 trees? The chief fact presented is a statement of the yield of fruit—one crop with a difference of 125 apples between the plats of 40 trees each. This is scant evidence from which to draw inference or conclusions.

So many of the important details of the method of conducting this experiment are lacking that even if the authors' con-

clusions be accepted for the Ohio Station orchard it would be extremely difficult to make applications of them to other conditions. Thus the brief statement that "the soil is quite uniform as to fertility and general character," without a word in regard to kind of soil, physical and chemical composition, depth and previous treatment, is not sufficient to permit wide application of the results of the experiment. As regards mulching there is only the statement that the trees in sod "were heavily mulched with straw."

How much straw per acre and the number of times of application are not given. Of the sod mulch trees the reader is told that they "were planted in sod" but whether blue-grass, orchard-grass, timothy, clover or a combination of these does not appear, nor the age of the sod, how much mulch per acre it would produce, nor when the grass was cut for mulching. An "annual turning under of a growth of leguminous plants" is spoken of but what the plants were, when planted or when turned under is left to conjecture. Even so important a matter as the relative cost of the two methods is not considered. Without these and other details it is almost impossible to gauge the value and applicability of the Ohio experiment.

Tillage is the rule for all domesticated plants. The horticultural authorities of the past have taught that thorough tillage is the best condition for the orchard. Practically all but the Ohio Station among the experiment stations of America now so teach. The burden of proof in the controversy over tillage and sod for the orchard rightly fell on the Ohio Station. It is assumed that they attempted to furnish such proof in this bulletin. But the Ohio investigators cannot convince without describing more fully their material, without allowing their readers to follow all the steps by which their discoveries are made, by making plain the logic of their conclusions, and by showing a more considerable body and a better quality of evidence than they have yet made public.

EXPERIMENTS BY THIS STATION.

The comparison of tillage and sod-mulch for the apple was begun by the New York Agricultural Experiment Station in the season of 1903 under the direction of Professor S. A. Beach, then Station Horticulturist. Experiments were started in two orchards in widely separated parts of the State and under very different environments; the investigation is to continue for five years to come. One of the experiments is located on the farm of W. D. Auchter, seven miles west of the city of Rochester; the other is on the farm of Grant Hitchings near Syracuse, New York. This report has to do with the Auchter orchard, work in the Hitchings orchard not having been carried far enough to warrant a formal presentation of results. The comparative inaccessibility of the latter orchard and the immaturity of part of the trees have made it impossible, as yet, to secure all the data needed for a thorough discussion of the experiment. Since the report covers only half the period the experiment is to run, it is not final.

THE AUCHTER EXPERIMENT.

The trees.—The Auchter orchard consists of a little over nine and one-half acres of Baldwin trees set in 1877 at a distance apart of 40 feet each way. There are 10 rows in the orchard, each containing 26 trees. The accompanying chart shows the location of rows and trees. Rows 1 to 5 inclusive are under sod-mulch treatment and rows 6 to 10 are tilled. A few trees in each plat, indicated in the chart, either because of marked inferiority or being of varieties other than Baldwin are not in the experiment. The number of trees in the sod-plat actually in the experiment is 118; in the tilled plat, 121. Previous to this experiment the trees had been under tillage with an annual cover crop. Plate XXV shows the adjoining edges of the two plats.

Topography and soil.—The topography of the Auchter orchard and the surrounding fields is typical of the western New York apple belt. Beginning at about the center of the orchard at the west end, and running diagonally lengthwise

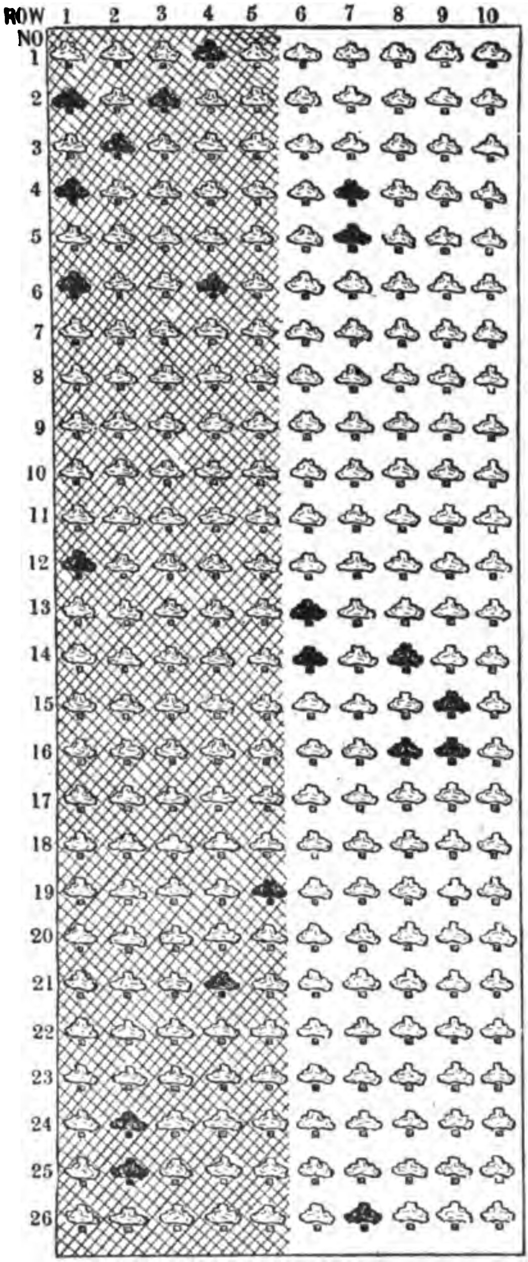

DIAGRAM I.— PLAN OF AUCHTER ORCHARD.

Dark shading, Sod; Light shading, Tillage; Trees in Black **not in** experiment.

toward the southeast corner, is a low and slightly stony ridge from which the land slopes gently to north and south. In the southwest corner, covering an area of nearly an acre there is a slight depression, possibly fifteen feet below the summit of the ridge. This hollow is tile-drained; the rest of the orchard is naturally drained.

The character of the soil changes somewhat with the topographical outlines of the orchard. On the ridge and high ground the soil is a fertile Dunkirk sandy loam to a depth of nine or ten inches, underlain by a compact sandy subsoil. In the depression the type changes to a dark colored Dunkirk loam, ten to twelve inches deep, and underlain by a very fine compact sand. The subsoil over the entire orchard shows a tendency to grow coarser at a depth of three feet and downward. The orchard was chosen for this experiment because the variations in soil were so few and slight.

Table I shows the composition of the soils and subsoils as determined by mechanical analysis. Table XI shows the water-soluble plant food in the soil of the Auchter orchard.

TABLE I.—COMPOSITION OF THE SOILS AND SUBSOILS IN THE AUCHTER ORCHARD.

Description	Coarse sand, 1–0.5 mm.	Medium sand, 0.5–0.25 mm.	Fine sand, 0.25–0.1 mm.	Very fine sand, 0.1–0.05 mm.	Silt, 0.05–0.005 mm.	Clay, below 0.005 mm.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Dunkirk Sandy Loam 0–9 inches...........	11.7	52.3	3.6	11.1	15.5	5.6
Subsoil................	9.0	60.5	7.1	9.7	8.4	5.1
Dunkirk Loam, 0–11 inches...............	4.4	26.2	9.7	30.0	19.1	10.6
Subsoil................	.3	15.6	21.5	27.9	29.0	5.5

MANAGEMENT OF PLATS.

The trees in the two plats of the experiment have received as nearly as possible identical care as to spraying, pruning, and all other orchard operations excepting soil treatment. The soil in the two plats has been managed as follows:

Sod plat.—October 15, 1903, eight quarts each of orchard grass and blue grass seed were sown per acre from which a fairly good stand was secured. To make sure, however, of a good stand of grass, a second seeding of sixteen quarts of blue grass, eight quarts of orchard grass and three quarts of timothy seed was made April 21, 1904. During the first season the grass flora was well divided between the above three grasses but the second year the orchard grass became dominant and has increased in quantity until now the plat is covered with an orchard grass sod. The grass has been mowed on the following dates during the five years of the experiment:

1904, June 21 and August 23.
1905, June 12 and August 14.
1906, June 18.
1907, June 27.
1908, May 27 and July 4.

The grass, if allowed to stand until haying time, would produce two tons per acre and when cut twice the crop would exceed this amount. The character of the grass growth is shown in Plate XXVI. It was in all cases allowed to remain where it fell from the mower as the roots of the trees spread over the entire orchard area and there was therefore need to mulch the whole area.

Tilled plat.—The following is a memorandum of the treatment of the tilled plat:

1904. Plat plowed June 7-11; ground harrowed June 13, June 20, July 19, July 29. Cover crop of mammoth clover sown July 30 and the seed harrowed in with a weeder.

1905. Plat plowed May 30; rolled June 5; harrowed June 13; June 26, July 7, July 22, August 2. Mammoth clover sown

August 3 and the seed covered with a weeder, followed by a roller.

1906. Plat plowed June 4-6; rolled and harrowed June 7; harrowed June 22, July 19, August 2. A cover crop of oats was sown August 2 and harrowed in the next day.

1907. Plat plowed May 27-29; land harrowed May 31, June 28, July 17, July 27, August 5. A cover crop of mammoth clover was sown August 6 and covered with a weeder.

1908. Plat plowed May 23-26; land harrowed May 27, June 4, 12, 23, and July 31. A cover crop of oats was sown July 31 and harrowed in the following day with a weeder.

Fertilizers used.—At the time this experiment was begun, there were few data to show what food constituents the orchard lands of the State need. It was commonly thought that the apple lands of western New York need phosphoric acid and potash and that the land of which that in the Auchter orchard is a type needs the former in particular. For the first three years of the experiment, therefore, 4,000 pounds of acid phosphate were used in the orchard, and cross rows 8 and 9, running through the tilled and sod plats were fertilized with muriate of potash at the rate of 400 pounds per acre. It could not be found that trees or cover crops were any the better for the application of potash in these two rows and it seemed from other data coming in that the phosphoric acid was being wasted as well. The fourth season, 1907, the general application of acid phosphate for the whole orchard was dropped, but the muriate of potash was continued on cross rows 8 and 9; and the phosphate was applied on cross rows 12 and 13 at the rate of 15 pounds per tree; on cross rows 16 and 17 the two fertilizers were combined in the quantities given above. During the season of 1907 no effects could be observed on apples, cover crops or grass. It is fair to conclude, therefore, that the additions of these two food constituents were not needed in this orchard and their use was discontinued in 1908. None of the plats to which fertilizers had been applied in past years showed any effects in 1908.

STATEMENT OF RESULTS.

The relative merits of different methods in orchard management are best gauged by the crops of fruit obtained. In commercial fruit growing in New York the amount of fruit is the most important criterion of merit, since buyers discriminate little as to the character of the fruit itself except as to blemishes; nevertheless it is important that all of the properties of the fruit, as size, color, time of maturity, flavor, flesh characters and keeping quality be noted. It is of course highly important that trees grow well; and for the measure of tree-vigor several characters are available. Those we have chosen are: Diameter of tree; amount, color and size of foliage; length, color and amount of annual growth of branches; and the root system. We come now to a discussion of these criteria of the merits of the two methods of orchard management in this experiment

Amount of fruit.—The five years during which this investigation has been in progress have been seasons of abundant apple harvests. In no one of the years has there been an apple failure or a condition approaching failure in this orchard. In considering the data as to amount of fruit it must be remembered that while the quantity of the crop is the most important criterion of orchard management, yet it is impossible to use it as an exact index of the performance of the trees; for the total quantity may be great, yet owing to the small size of the apples the value may be small; or, if the quantity of apples be small and the size of the fruits large, the crop may be of comparatively high value. There seems to be no satisfactory way of establishing an exact measure of value which will include these conditions and we are forced therefore to make use of total quantities of commercial grades as the nearest approach to the true value of the crop. Table II gives these data.

TABLE II.—YIELD OF FRUIT ON SOD AND TILLAGE PLATS.

Year	Sod Plat—118 Trees				Tilled Plat—121 Trees				Diff. in favor tillage
	1st class	2nd class	Culls	Total yield	1st class	2nd class	Culls	Total yield	
	Bbls.	*Bbls.*	*Bbls.*	*Bbls.*	*Bbls.*	*Bbls.*	*Bbls.*	*Bbls.*	*Bbls.*
1904.......	278	51	*286.1	615.1	269	47	*275.9	591.9	—23.2
1905.......	123.3	38	71.7	233	149.3	34	95.6	278.9	45.9
1906.......	135.3	32	43	210.3	255.3	†90	†185.8	531.1	320.8
1907.......	144.3	44	87	275.3	248.3	63	113	424.3	149
1908.......	255.3	17.5	52.5	325.3	480.3	‡60.5	‡181.7	722.5	397.2
Avg......	187.2	36.5	108	331.8	280.4	58.9	170.4	509.7	177.9
Avg on basis of 121 trees	191.9	37.4	110.7	340.2	280.4	58.9	170.4	509.7	169.5
**Acre Avg.	41.1	8	23.7	72.9	60	12.6	36.5	109.2	36.3

* A September storm blew half the crop from the trees.
† Increase in culls and seconds due to aphis injury of fruit.
‡ Increase in culls and seconds due to curculio injury of fruit.
** On basis of 27.2 trees per acre.

The table needs little amplification. The last column, showing the differences between the yields on the two plats, is by far the best measure of the value of the two methods of orchard management. It is proper that seconds and culls should be included in this column. The fruits of these grades are often as large as the first grade apples—graded low because of imperfections. These of course require as much food for their development as perfect fruits of the same size. Moreover, small fruits take a greater comparative amount of moisture and plant food from the soil than large fruits for they have a greater proportion of solid matter than large fruits, the seeds being as many in one as the other.

Taking, therefore, the difference in total yield of fruit between the two plats as the measure of value of the two treatments, it is shown clearly that tillage is the better way of handling this orchard. In brief, the figures show that tillage gave a very considerable total gain for the five years; that

yearly the difference in favor of tillage is becoming more marked; that the tilled trees are yearly increasing their bearing capacity; and that, to the contrary, the fruitfulness of the sod-mulch trees is decreasing, showing that the treatment is not only less beneficial than tillage but that it is positively harmful to the trees.

Number and size of fruits.—Size of fruit need be considered in discussing this experiment only as it has a bearing upon marketable quantity. Size is desirable in a culinary apple because it saves waste in paring and coring, but for a dessert fruit a medium-sized apple is usually preferred. We may, therefore, drop size as affecting intrinsic value of the crop. The question arises then: Is the increased quantity due to more apples on the tilled plat, or, are the apples larger on the tilled than on the sod plat? Tables III and IV throw light on this question.

Table III.—Amount of Bloom Compared with Amount of Fruit, on Sod and Tillage Plats.

Year	Sod plat		Tillage plat	
	Percentage bloom	Amount fruit	Percentage bloom	Amount fruit
	Per ct.	*Bbls.*	*Per ct.*	*Bbls.*
1905	31.8	233.	31.3	278.9
1907	21.6	275.3	36.4	424.3
1908	25.3	325.3	55.4	722.5

Table III shows from estimates made from each tree the amount of bloom in the orchard for three years. Unfortunately the blooming records were not taken the other two of the five years. A comparison of the percentage of bloom on the trees with the amount of fruit harvested, shown in the same table, makes plain that there is a close relationship between the number of blossoms and the number of fruits. That

is, about the same percentage of blossoms in each plat set fruits. This being true, the table shows that there is a far greater number of fruits produced on the tilled plat. In the next table an idea is given of the relative size of the apples from the two plats.

TABLE IV.—SIZE OF APPLES ON SOD AND TILLAGE PLATS.

Plat	Number of apples per barrel	Weight per barrel	Average weight of apples
		Lbs.	*Oz.*
Sod	434	136	5.01
Tillage	309	136	7.04

Table IV gives the average number of apples per barrel of first grade fruit from each of the two plats and the average weight of the individual specimens. This table shows that the tilled apples average larger than those grown in sod.

The last two tables substantiate what is apparent from observation alone to those who have been in the orchard; namely, that the increase in quantity of fruit on the tilled plat over the sod plat is due both to the greater number of fruits and larger size of specimens. It is apparent, too, that if the relative size, indicated by the proportion of 5 to 7, holds for the whole crop, as we think it does, there are a greater proportion of culls and seconds in the sodded than in the tilled plat when size alone is considered.

Color of fruit.—The fruit from the sod-mulch plat is much more highly colored and therefore more attractive in color than that from the tilled plat. The difference varies somewhat with the season. Mulched trees ripen their fruits earlier than tilled trees and if the weather is sunny and propitious for the proper coloring of apples, and if the tilled fruit can remain on the trees one or two weeks longer to mature, as it should, the difference is less marked than otherwise as to color.

This is the one respect in which the sod-mulched fruit surpassed the tilled. But since in every possible test in this experiment the tilled trees are shown to be most vigorous, and since wounded, diseased, weak-growing or decrepit trees always bear fruit of high color, and conversely well nourished trees often bear poorly colored fruits, it can be said that the bright color of the sod fruit is the hectic flush of disease or of decrepitude. Of the several indications of the deleterious effects of grass in the orchard the abnormally high color is one of the most marked. The bright red of the sod-mulch fruit is purchased at the expense of the health and vigor of the trees.

Maturity of fruit.—The fruit on the sod-mulch plat is mature enough to pick from one to three weeks earlier than that on the tilled plat. If the season is wet and cool the difference in ripening time is small, if dry and warm it is great; and so great as to make early maturity a serious evil outcome of the sod-mulch method of orchard management. For example, in this dry and warm season, 1908, the difference in ripening time was fully two weeks. In all of the five years the sod-mulched fruit has ripened materially earlier and has been picked first.

Keeping-quality of fruit.—The difference in keeping quality of the fruit from the two plats is even more marked. At this writing, November 14, 1908, the sod-mulched apples kept in common storage are at their prime, while the tilled fruit is still firm and just reaching edible condition. There is more than a month's difference in the keeping properties of the fruit from the two plats. The differences have been similarly marked, though in less degree, in the past years, warranting the statement that the tilled fruit will keep a month longer in common storage than the sod-mulched product.

The following statement from Mr. G. Harold Powell, Pomologist in charge of Fruit Transportation and Cold Storage Investigations in the United States Department of Agriculture, is a record of the keeping qualities of the fruit from the two plats in cold storage.

"For five years, since 1904, the Bureau of Plant Industry has stored fruit from the sod and the cultivated trees in the Auchter orchard. From 1904 to 1907 inclusive the apples were stored in a temperature of 32 degrees F. in Buffalo, N. Y., and in 1908 in the same temperature in Washington, D. C. The fruit has been packed in 50-pound boxes.

"There was little difference in the character of the fruit from the two plots in 1904 either in color or in keeping quality. The fruit from the sod trees was a few shades darker in color, but both lots contained large, well-colored though rather dull apples. Both kept in good condition throughout the commercial storage season, which ends April 30th.

"In 1905 both lots were in equally good condition at the end of the commercial storage season as regards physical condition and the fruit from the sod trees was darker in color and much brighter in general appearance.

"In 1906, two pickings were made from each plot, the first October 10 and the second October 24. The fruit from the sod trees was darker in color than the tillage fruit in each picking. The fruit of the second picking from the tillage trees was much better in color than that of the first picking, but not as bright in color as the apples picked at first from the sod trees. The best colored apples were from the last picking from the sod trees.

"The fruit from all lots kept in equally good condition to March 1st. While the tillage apples were not equal to the sod fruit in appearance, the flavor and texture of the sod fruit were distinctly inferior. The texture of the sod fruit was coarse and the flavor was insipid, with a trace of bitterness in it. The tillage apples were brittle and semi-firm in texture, aromatic and good in flavor.

"When the fruit was examined again May 1st, the same distinct difference in flavor was present. The best flavored fruit was picked from the tillage trees October 24. There was no decay in any of the apples at this time, but the scald had developed on the partly-colored apples from the tillage trees to a greater extent than on the better colored fruit from the

sod trees. The scald on the different lots May 4th is shown in the following statement:

	First Picking.	Second Picking.
Scald on sod fruit..........	16.4 per ct.	18.7 per ct.
Scald on tillage fruit.......	60.7 per ct.	35.0 per ct.

"In 1907 two pickings were again made, the first October 7th, the second October 19th. The fruit from the sod trees was darker in color, and the color of both lots was better in the fruit of the second picking. All lots kept in prime condition till the end of the commercial storage season. There was a distinct difference in quality in favor of the apples from the cultivated land, the fruit from the sod trees though finer in color having a coarse texture and an insipid slightly bitter flavor.

"In 1908, the fruit was handled in a manner similar to that of 1906 and 1907. At the time this report is made, February 8, 1909, there is considerable Baldwin spot in the different lots of fruit and the apples from the cultivated trees though of poorer color were finer in quality than the fruit from the sod trees."

Quality of the fruit.—There is but little difference in the quality of the fruit when specimens can be had at the same degree of maturity. But as we have seen in the preceding paragraph the tissues of the sod-mulch fruit begin to break down so quickly after harvesting that at any time after this period the tilled fruit is better in quality. This has been true in all of the five seasons, a fact affirmed by repeated testing by those in charge of this experiment; by experimenters in the United States Department of Agriculture, as stated in the preceding quotation from Mr. Powell; and attested by many who have seen the fruit at this Station, at horticultural meetings and at farmers' institutes. The more pleasing color of the sod-mulch fruit leads many to think it is of higher quality but it requires only a taste to convince to the contrary.

The difference in quality is due chiefly to a difference in the texture of the flesh. In eating, the tissues of the tilled fruit

are turgid and crisp while in the apples from the sod-mulch plat there is a tendency to dryness and mealiness. A determination of the water content, however, does not show much difference in this respect, the tilled fruit having 84.37 per ct. moisture, the sod-mulch fruit 84.17 per ct. There is no appreciable difference in the specific gravity of the must of the fruit from the two plats as indicated by the hydrometer, showing that the percentage of soluble solids is practically the same in the two products.

There are noteworthy differences in the flesh of the two fruits. That of the apples from the sodded trees is yellowish in color and frequently tinted with red at the circumference while that of the apples from the tilled trees is greenish and never tinted. Of more importance commercially is the fact that the flesh of the sodded fruit is more frequently spotted with the "Baldwin spot," a dry, corky condition of portions of the flesh due probably to some physiological trouble. This corky tissue sometimes envelops the core and in other specimens involves not a little of the circumference of the fruit. Such a physiological defect must be considered as a result of some harmful disturbance in the well-being of the tree.

Uniformity in trees and crop.—In commercial orcharding it is greatly to be desired that trees behave uniformly,—especially in the matter of bearing crops. A method that causes a tree to bear annually, or to bear a crop of fruit of uniform size, or to have its load well distributed, is a more valuable method than one that does not secure uniformity in these respects. The advantage of tillage over the sod-mulch system in the matter of uniformity is most marked. Not so much in the matter of annual bearing, for the Baldwin rarely bears annually under any treatment, but greatly so as to the size of fruit, the distribution of the crop on the tree, and in the performance of individual trees. The trees in sod showed marked abnormalities in their tendency to produce large fruits or large crops on a part of the tree, and small fruits or none at all on another part. Of two trees standing in sod, side by side, one would bear large fruit, the other small; one a crop,

the other none; one well colored fruits, the other poorly colored specimens. These are but illustrations of the freakishness of the sod-mulched trees. Branches and foliage showed similar tendencies to depart from the normal.

One need not seek long for an explanation of such behavior of the trees. No matter how uniform the sod (Plate XXVII shows the sod in the Auchter orchard to be as uniform as sod often is in orchards) there will be areas well grassed and areas poorly grassed; areas in which there is an admixture of some plant not to be found in the same quantity elsewhere. Now this lack of uniformity of environment cannot but bring about ununiformity in the trees themselves. On the contrary, tillage is conducive to a uniform environment as it secures surface uniformity of the field, equalizes the depth of soil; and tends to evenness in the amount and availability of moisture and food. One of the reasons for cultivating any crop is to secure an equally vigorous growth over the entire area cropped.

Effects of the two treatments on the tree.—In the long run, crop performance measures the vigor and health in a plant but in period of so few years as the one in which this experiment has been in progress it is possible for trees to have a high record in bearing fruit and yet lose in vigor. It is necessary, then, to consider the effects of the two methods on the trees. It is not fair to measure the effects of a treatment by considering one or a few phases of tree growth. It may be that all tree characters do not respond in exactly the same degree to treatment. If, however, the methods of gauging vigor are correct there should be fairly close agreement in the growth of different parts of trees as affected by the two treatments. Thus in all of the fruit characters indicating vigor, the advantage has been strongly with tillage; so, it will be found, too, in all tree characters, tillage has promoted greater vigor and health than the sod-mulch.

Diameter of trees.—The vigor of trees is almost directly proportional to the increase in diameter of the trunk. We examine the rings in a cross-section of a tree and tell of the good and poor seasons in its life by the thickness of the rings.

If we had but one phase of growth by which to measure vigor, and especially over a series of years, increase in diameter of trunk should take first place.

Table V shows the gains in diameter of the trunks under the two methods of treatment. In making these measurements diameters were taken one foot above the ground and one foot below the lowest branches, the length of the tree trunks averaging in this orchard about four and one half feet. The final figures are averages between these two measurements. The data in this table show clearly and most strikingly the greater vigor of the tilled trees.

TABLE V.—GAIN IN DIAMETER OF TREE TRUNKS ON SOD AND TILLAGE PLATS.

Year	Sod—Average of 118 Trees					Tillage—Average of 121 Trees				
	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7	Row 8	Row 9	Row 10
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1908..........	15.2	15.2	14.5	14.9	14.1	15.0	14.5	15.8	15.9	17.0
1904..........	13.6	14.1	13.5	14.1	13.1	12.9	12.4	13.6	13.8	14.7
Gain.......	1.6	1.1	1.0	0.8	1.0	2.1	2.1	2.2	2.1	2.3
	Avg. gain for Sod=1.1 in.					Avg. gain for Tillage=2.1 in.				

The foliage.—The foliage is as ready a gauge and as delicate a one to determine the health of a tree as is the pulse in a human being. All leaf characters indicate greater vigor of tree from tillage. The tell-tale tints of the leaves spoke most eloquently of the superior vigor and health of the tilled trees in this experiment. So, too, the size of the leaves, their number and weight, the total leaf area and the length of time the leaves remained on the trees, proclaimed, with color, that tillage is the better method of orchard management to obtain health and vigor of tree. Yet because of the countless numbers of leaves on a tree and the great variation between individuals

it is difficult to furnish accurate, specific evidence as proof of the above statement. Reliance must be placed upon the accuracy of observation of the experimenters. Since, however, leaf characters reflect so delicately the health of a plant, it does not need even the accuracy of a practiced eye to gauge the well-being of a tree from the leaves.

Color of foliage.—It required only a glance to detect a difference in the color of the foliage in the two plats and to note that something was amiss with the leaves of the sodded trees. The dark and rich green of the tilled trees indicated an abundance of food and moisture and the heyday of health, while the pale and sickly foliage of the sodded trees suggested drouth, starvation or some serious physiological disturbance. To the casual visitor this was the most apparent sign of the superiority of tillage and more than one man of the hundreds who visited the orchard was heard to say as his eyes lighted on the contrasting colors of tilled and sodded trees, "that satisfies me." The absence of color in the leaves of the sod-mulch trees is due to a lack of chlorophyll or leaf-green. Chlorophyll is essential to the assimilation of plant food and without a sufficient quantity plants must suffer from mal-nutrition. Its lack must be counted as both a cause and an effect of the ill-health of the sodded trees.

Area of foliage.—No feasible plan could be found for taking the leaf area of individual leaves, the total leaf area, or the number of leaves on the trees in the two plats. But here again it was easy to see that the leaves of the tilled trees were much larger, and much more numerous, and that therefore their total leaf area was much greater. In fact some practical orchardists found fault with the foliage of the tilled trees, saying that the size and number of the leaves indicated too much wood growth and shut out sunlight thus preventing the proper coloring of the tilled fruit.

Weight of foliage.—The comparative weights of the leaves in the two plats were ascertained as follows: Groups of 10 leaves each from the ends of the shoots on 5 sides of 48 trees in each plat were taken—2,400 leaves from sodded and the same

number from tilled trees. These were weighed and gave 8.7 grams as the average for the leaves of the sodded trees and 11.5 grams for those of the tilled trees, making the leaves of the tilled trees one and one-third times as large as those of the sodded trees. This means, roughly speaking, that the assimilating powers of the tilled trees, considering size and taking no account of number of leaves, is one and one-third times as great for the tilled as for the sodded trees.

Leafing-time.—In the time of leafing there was a difference of three or four days, the leaves of the tilled trees opening first, probably because of the warmer soil. The leaves on the sod-mulch trees took on their autumnal tints a week or ten days earlier than did those of the tilled plat. As a natural consequence the foliage of the sodded trees dropped that much earlier, thus cutting short the growing season of the grassed trees and without doubt impairing not a little their future vitality and hastening the maturity of the fruit. But the shedding of foliage lets in the sun to give better color to the fruit, an advantage which offsets in some degree the disadvantage of early dropping of foliage.

There was apparently little difference in the blooming time of the two plats, though observations did not cover all of the years and were not carefully enough made to warrant an exact statement in this regard.

Annual growth of branches.—The annual growth of new wood is a most important criterion of the well-being of an apple tree, because it is not only a measure of vigor but of the bearing capacity, since buds may be formed on any of the wood older than one year. This is, however, a most difficult measurement to make since there is a wide variation in the annual growths of trees and even in different parts of trees. The plan first adopted in this work to show difference in annual growth was to take new wood from all trees but it was found that in this respect "outside" trees were too variable and averages therefore were taken only from "inside" trees. For the sod plat growths were taken only from the following: Trees 2 to 25 inclusive, rows 2 and 4; for the tilled plat,

Plate XXV.—Tilled Plat and Sod Plat with Grass at Cutting Time.

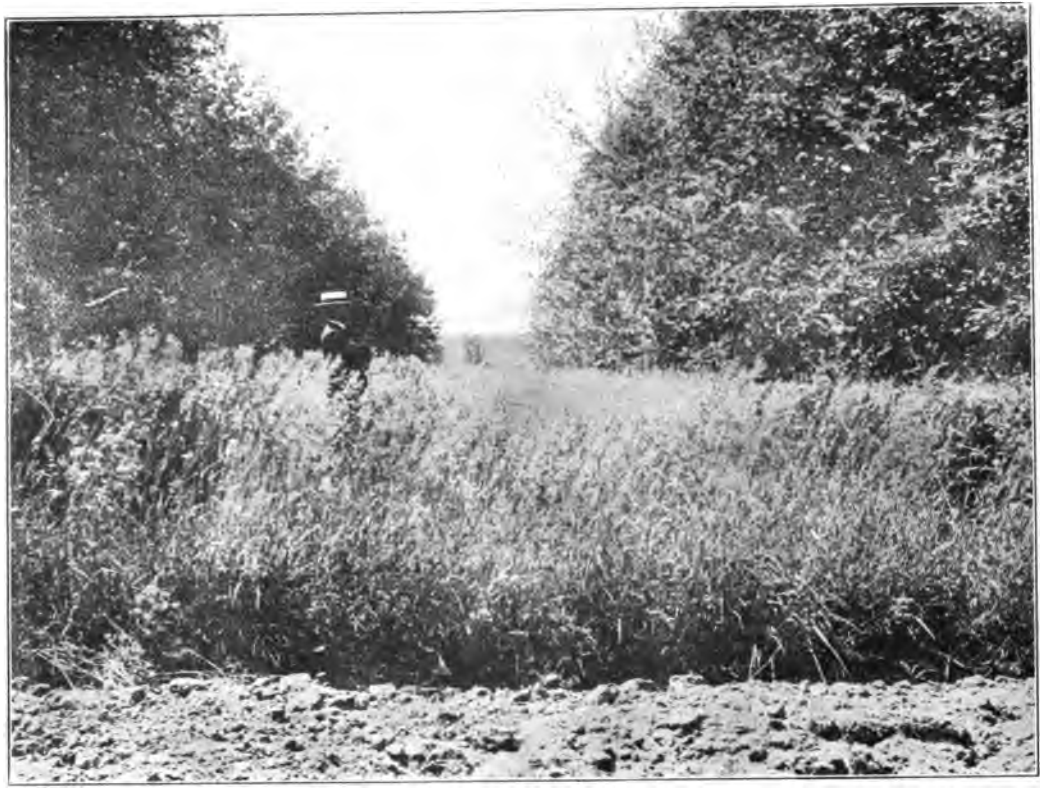

PLATE XXVI.—GRASS ON SOD PLAT WHEN LEFT UNCUT UNTIL HAYING TIME.

trees 2 to 25 inclusive, rows 7 and 9. For measurements, branches covering five years' growth were cut on five sides of each tree, 240 branches for each plat. The comparisons between branches and twigs from the tilled and sodded trees are shown in Plate XXVIII.

The averages in Table VI show, as in all other criteria so far examined, a great loss of vigor on the part of the sod-mulched trees. The growth for five years on the tilled land lacks but a trifle of being twice that on the sodded land. The growth is less from year to year on both plats, with the increasing age of the trees, but the yearly decrease is much greater on the sodded than on the tilled trees; the falling away being from 5.8 inches in 1904 on the sod to 1.9 inches in 1908; while in the tilled plat it was 7.9 inches in 1904 and 5 inches in 1908.

Table VI.—Average Length of Annual Growth and Averagr Number of Laterals on Sodded and Tilled Apple Trees.

Year	Sod	Tillage
	In.	*In.*
1904	5.8	7.9
1905	4.2	7.2
1906	2.7	6.5
1907	2.5	6.9
1908	1.9	5.0
Total	17.1	33.5
Average annual growth	3.4	6.7
Average number laterals per year	1.9	4.4

As the measurements of length were taken the numbers of laterals made each year were counted. These are per year for the sod trees 1.9; for the tilled trees, 4.4. The number of side shoots on each year's growth shows that in neither case was the new wood soft and sucker-like. They show, too, that there was a possibility for many more fruit-spurs on the new growths of the tilled trees than on those of the sod trees.

Still another indication of the superiority of the wood for five years from the tilled trees is found in the greater weight of the wood from the tilled trees. When the 240 branches from each plat had been measured for annual growths the weights of the wood were taken. It was found to be 7.2 pounds for the sod and 21.3 pounds for the tilled trees—strong testimony to the greater health of the tilled trees.

Color of new wood.—During the dormant season there is a striking difference in the color of the new wood of the trees on the two plats. The whole tree top on the tilled land is a light, bright, glossy olive-green color, emphasized somewhat by the plumpness of the twigs and the tautness of the bark. The tree tops on the sod-mulch plat were darker, of a brownish cast and less glossy and bright, giving a prevailing color that distinguished the sod-mulch plat from the tilled plat a mile away. One cannot well describe the color of wood on healthy trees and that on trees which lack vigor but the practiced eye of the nurseryman or fruit grower discerns a difference at a glance. Only a look was needed at the trees in these two plats, with or without foliage, to be convinced that the tilled trees were in the very perfection of health and that there was something amiss with the sod-mulch trees.

Dead wood.—In trees as old as these in this experiment there is always some dead wood, usually on lower branches, though now and then a limb succumbs seemingly without cause in any part of the tree top. It is a sign of failing vigor and decrepitude if there is much of this dead wood. As this experiment has progressed the amount of dead wood in the sod-mulch plat has increased until at the end of the fifth year there is scarcely a tree without a showing of dead branches. In no case is there enough to cause fear for the life of the tree, but in many trees the number of small branches, dead or dying, makes it certain that the trees are seriously out of health.

The root system.—Of all the organs of the tree the roots bore strongest testimony to the deleterious effects of the grass in the sod orchard. This is as might be expected; for the roots are possibly the most sensitive of plant structures, responding to

the influence of gravity, air, heat, light, moisture, food and chemical compounds. So sensitive are roots to external conditions that it may be laid down as a law that the character of a root system is directly determined by the interaction between the specific peculiarities of the plant itself and of its environment. Thus in size, position, and shape a root system is greatly modified by the external conditions. In the experiment in hand it is the root system that comes in first and most direct contact with the differing factors in the management of the trees of the two plats. The apple trees were forced to accommodate their root systems to the conditions given in the two plats of the experiment. In what condition did the two treatments leave the roots at the end of the five years? We can give fairly definite answer as regards position and shape but as to size of the roots we can only roughly estimate.

Position of roots.—In position the roots of the trees in the sod-mulch plat came to the very surface of the ground, oftentimes being found in the decaying mulch. The great mass of the feeding roots in this plat lie close to the surface though straggling roots, rootlets and roothairs go to the full depth of the foot of the light soil of which this land is composed. Whether the destruction of these surface feeding rootlets by cold in winter and heat and drought in summer greatly affected the vigor of the trees and helped to bring about the evil effects of the sod-mulch treatment cannot be said. It is not likely that cold contributed much to the injury of the sodded trees but the death of many of these surface roots in hot, dry weather must have lessened the vitality of the trees at a most critical time for the welfare of crop and plant. In the tilled land the roots were to be found in greatest abundance at a depth of from three to ten inches, with some running deeper. The plow and cultivator kept them from coming nearer the surface, though, since plants direct their root-tips to places where food and water are most abundant and with cultivation water at least would be most abundant under the earth mulch, it is doubtful if many roots pass into the mulch made by the cultivator.

Shape of root systems.—But by far the most remarkable difference in the root systems of the trees in the two plats is in the shape. The roots of the tilled trees spread out much as do the branches, with a sweep not much greater than the branches. The circumference of the root system of such a tree is nearly circular, with the feeding roots in a plane of six or eight inches. But the circumference of the root system of the trees in sod is very irregular with many offshoots in this direction and that, and with much more unevenness as to depth. The great irregularity in the root system of these trees must be due to some force or forces which attracts them from the normal. There is a reaching out of a part of the roots in response to a demand for more moisture, food, or air, or all of these, or to escape some evil effect of the grass roots. This unevenness of growth is shown in Plate XXIX where the roots of a tree in sod are shown in the adjoining tilled land at a distance of from 20 to 30 feet from the tree; again in Plate XXX a large root and its branches, rootlets, and roothairs are shown passing under a stone wall into a lane to a distance of from 30 to 40 feet. These abnormalities were not to be found in the root system of the tilled trees.

Quantity of roots.—There is no fair way of comparing the size, quantity or bulk of the roots of the trees in the two plats. To obtain such data at all accurately would mean the removal of some of the trees and even then countless numbers of rootlets would be destroyed. It is not possible to remove a given bulk of earth from the two plats and so measure the quantity of functioning roots with accuracy; for, in the sod the masses of roots have been accumulating for six years while in the tilled land there has been a yearly pruning by the plow and the consequent formation of new roots. Were the data as to quantity obtainable, it would be difficult to draw conclusions from them as almost nothing is known of how much work roots can do. Thus a small root system may do quite as much work in one soil or environment as a large root system would in another; so, too a mass of roots may be large and bulky with functionless roots while a smaller one may contain only live

active organs. It is known, too, that the powers of accommodation to conditions are great in the roots of all plants. We must measure the value of a root system not by its bulk but by what it does.

The "outside row."—One of the interesting phases of the experiment in the Auchter orchard was the behavior of the trees in the outside row of the sod-mulch plat. This plat was bounded on the east and west by the tilled fields of the Vick seed farm; on the north by the tilled plat of this experiment and on the south by a long used cattle lane. An area of sod 20 feet wide separated the trees in the plat from the adjoining territory. As the visitor approached the Auchter orchard the most noteworthy thing in the experiment was the comparatively green and luxuriant foliage and the greater quantity and larger size of the fruit on the trees on the outside row of the sod-mulch plat. There was a marked difference even in the halves of the trees lying toward the inside or the outside of the plat in favor of the outside. Since 55 of the 118 trees in the sod-plat are outside trees, it is not too much to say that the showing made by the sod-mulch plat has been greatly bettered by reason of greater vigor and productiveness of these outside trees.

It is a fact that the outside row in an orchard, or in any field of cultivated plants, is usually somewhat better than the inner rows; the outer rows get more air, sunlight, wind, food and moisture. But the great difference in this case, a difference scarcely noted in the tilled plat, is abnormal and shows an abnormal environment for the sod-mulch trees. It has been stated in a previous paragraph, and Plates XXIX and XXX cited, that the roots of the trees in sod at every opportunity passed the division line between sod and no-sod either in quest of food, moisture and air or to escape proximity to grass roots. It is to the fact that the roots of the trees in the outside rows have gotten out of the sod that we must attribute the greater vigor and productiveness of the outside row in this orchard. Table V shows a gain of 1.6 inches in diameter for outside row 1 of the sod-mulch plat bordering the lane (see Plate

XXXI), while the four inner rows made an average gain of but .97 inch. It is true that the outside row in the tilled plat also made a greater gain than the inner rows but not nearly so great—being 2.3 inches for the outside row and 2.1 inches for the inner rows.

Surface wash.—The land in the Auchter orchard is rolling, though nowhere are the slopes steep. In this respect it is a fair average of the apple orchards of western New York. At no time has there been any harmful surface wash in either of the two plats and we have not, therefore, had an opportunity to observe in this orchard the influence of cultivation on surface wash. Since tillage is objected to on hilly ground because it is supposed to favor surface wash, it may not be out of place to give observations from elsewhere in this regard.

In all but the steepest locations in the climate and on the soils of New York, embracing practically all sites upon which trees can be sprayed, harvested and pruned with sufficient easiness to make fruit-growing profitable, proper cultivation may be made an efficient means of lessening the washing of land. Whatever contributes to the porosity of the soil prevents washing. It is obvious that cultivation makes a soil granular and porous. Plowing and tillage to check surface wash on steep slopes should be as deep as possible; furrows should run at right angles to the slope to impede the fall of the water; in some cases open furrows and ditches having a very gentle fall can well be maintained. If the above means of stopping surface wash be supplemented by cover-crops, which check the wash at the season when the rainfall is heaviest, it can be said that almost any land upon which it is practicable to grow fruit can be cultivated. Such deep-rooting cover crops as the clovers and cow-horn turnips are of great value on land that washes because they form root tubes which help to take care of the water. Artificial drainage is sometimes necessary on hill sides to prevent land from becoming water-logged, which of course would favor washing. There need be little solicitude about surface wash on most of the fruit lands of New York if proper precautions are observed where it is menacing.

Insects, vermin, fungi, and other troubles.—Entomologists usually hold that insects are more troublesome in sod mulched orchards than in those under tillage. Thus, Slingerland[6] states that the canker worm, curculio, borers, bark lice and the rosy apple aphis, are more abundant in uncultivated than in cultivated orchards. The insect fauna, so far as it relates to orchard pests, has been carefully studied in the Auchter orchard during the past five years the results of which may be summed up as follows:

Case-bearers, codling moth and the leaf blister mite were equally destructive in the two plats. The green aphis and the curculio did more damage on the tilled trees, but whether because the more luxuriant foliage was better to the taste of the pests or because the tilled plat was bounded on the north with woods, can not be told. Scurfy scale, oyster-shell scale and woolly aphis were without question far more abundant on the sod-mulch plat at the end of the five years. With all of the insect pests the effects are less apparent on the tilled trees because of the greater vitality of the latter; this is especially true of the work of the leaf blister-mite.

The orchard has been almost wholly free from fungi. The trees are old enough to withstand the attacks of mice and rabbits, pests commonly more abundant in sodded than in tilled lands. Throughout the State during the dry season of 1908 a number of sodded orchards have been destroyed or severely injured by fire but the sodded plat in this experiment has escaped any such calamity, though the mulch has been dry enough to burn had the fire started.

FINANCIAL STATEMENT.

One of the chief advantages claimed for the sod-mulch method of caring for an orchard is that of cheapness. Table VII gives the expenses and the income of the Auchter orchard for the past five years deducting all items that would not occur in the care of a commercial orchard. The average cost per

[6] New York State Fruit Growers' Association Report, 1908:19.

acre of the two methods of management, not including harvesting, was $17.92 for the sod and $24.47 for tillage, giving a difference of $6.55 in favor of the sod. The average net income per acre for the sod plat was $71.52; the tilled plat $110.43; a difference of $38.91 in favor of tillage—an increase of 54 per ct. for tillage over the sod-mulch method of management. The outgo has been greater for the tilled plat but the income has been more than proportionately greater showing that cheap methods in an orchard are not necessarily the most remunerative.

TABLE VII.—EXPENSE AND INCOME FROM SODDED AND TILLED PLATS.

SOD PLAT—118 TREES.

Year	Fertilizer	Pruning	Cutting grass	Spraying	Harvesting crop	Total expense	Net income
1904	$15.05	$14.62½	$19.99	$58.22½	$219.25	$327.14	$225.76
1905	18.60	13.25	7.46	44.27	82.89	166.47	330.28
1906	17.00	15.12	3.36	46.51	104.30	186.29	154.96
1907	8.37	15.33	3.67	73.84	138.07	239.28	487.16
1908	——	16.86½	6.14	50.45	173.43	246.88½	353.86½
Total	$59.02	$75.19	$40.62	$273.29½	$717.94	$1,166.06½	$1,552.02½

TILLED PLAT—121 TREES.

Year	Fertilizer	Pruning	Cultivation	Spraying	Harvesting crop	Total expense	Net income
1904	$15.05	$14.62½	$33.75	$58.22½	$210.90	$332.55	$185.34
1905	18.60	13.25	48.71	44.27	96.85	221.68	355.60
1906	17.00	15.12	30.30	46.51	231.80	340.73	392.42
1907	8.37	18.31	46.63	73.84	224.20	371.35	800.31
1908	——	22.10½	36.67	50.45	338.59	447.81½	723.41½
Total	$59.02	$83.41	$196.06	$273.29½	$1,102.34	$1,714.12½	$2,457.08½

Average income per acre, on basis of 27.2 trees, sod, $71.52; tillage, $110.43. Percentage of increase of tillage over sod, 54 per ct.

Plate XXVII.— Showing Uniformity of Sod in Sod Plat.

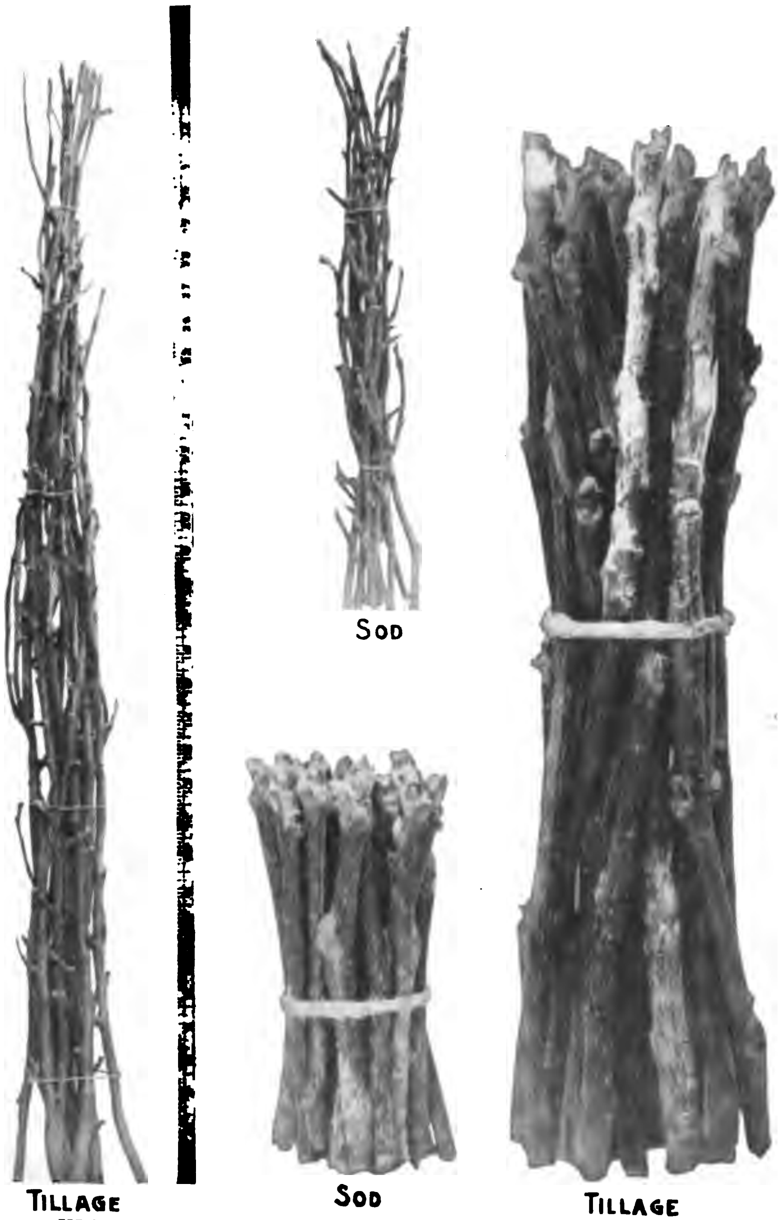

PLATE XXVIII.— COMPARATIVE GROWTH OF WOOD ON SOD AND TILLAGE PLATS.
Twigs Show One Year's Growth; Branches Five Years' Growth.

WHY TILLAGE IS BETTER THAN SOD FOR THE APPLE.

The greater value of tillage in the Auchter orchard is conclusively proved by the data given in the preceding pages. The question now arises. Why? What are the causes of the differences that have been noted between the trees in sod and under tillage? These causes may be divided into two general groups: The beneficial effects of tillage; and the injurious effects of grass. It would be conducive to clearness if the causes might be discussed under the above heads but in few cases can the positive effects of tillage and the negative effects of grass be separated. Thus there is more moisture for the trees in the soil of the tilled plat because the tillage has conserved moisture and because the grass has removed that which would otherwise have gone to the trees in the sod plat. So, in general, the differences between the two plats in favor of tillage have been brought about by a good effect from tillage plus a bad effect from the grass.

The tilled trees are better watered.—Liebig's "law of the minimum," according to which the yield of a given crop will be limited by the amount of one constituent of food, is now very generally applied to all of the factors affecting the growth of plants. If applied to the possible factors that have produced the results in this orchard it shows that one alone is quite sufficient to account for the differences noted—namely, the supply of water.

The results of 120 moisture determinations in the Auchter orchard in 1907 and 1908 are shown in Table VIII. The weight per acre-foot, 43,560 square feet one foot deep, for a sandy loam, according to Hilgard,[7] is approximately 1,800 tons. The average amounts of water in the soil at any time during the period of investigation are shown in Table IX.

[7] Soils. By E. W. Hilgard, New York: 1906. p. 107.

TABLE VIII.—THE MOISTURE CONTENT OF SOD AND TILLED PLATS.

1907				1908			
Date	Plat	1–6 in.	6–12 in.	Date	Plat	1–6 in.	6–12 in.
		Per ct.	*Per ct.*			*Per ct.*	*Per ct.*
6/28	Tillage.....	12.71	12.90	7/7	Tillage.....	12.77	11.56
	Sod........	6.23	6.31		Sod........	11.59	10.70
	Difference..	6.48	6.59		Difference..	1.18	.86
7/2	Tillage.....	14.88	14.86	7/10	Tillage.....	12.43	10.89
	Sod........	11.20	6.99		Sod........	6.62	6.29
	Difference..	3.68	7.87		Difference..	5.81	4.60
7/5	Tillage.....	12.07	10.96	7/14	Tillage	12.69	10.58
	Sod........	5.87	3.37		Sod........	9.00	6.03
	Difference..	6.20	7.59		Difference..	3.69	4.55
7/9	Tillage.....	13.12	12.04	7/22	Tillage.....	18.31	17.76
	Sod........	6.96	6.53		Sod........	14.02	9.59
	Difference..	6.16	5.51		Difference..	4.29	8.17
7/12	Tillage.....	16.43	15.31	7/24	Tillage.....	15.25	16.14
	Sod........	13.51	9.26		Sod........	11.85	9.37
	Difference..	2.92	6.05		Difference..	3.40	6.77
7/16	Tillage.....	13.77	11.75	7/28	Tillage.....	12.40	11.67
	Sod........	9.63	8.69		Sod........	10.84	8.25
	Difference..	4.14	3.06		Difference..	1.56	3.42
7/19	Tillage.....	11.68	9.48	7/31	Tillage.....	15.50	15.66
	Sod........	9.51	7.80		Sod........	13.31	10.09
	Difference..	2.17	1.68		Difference..	2.19	5.57
7/23	Tillage.....	13.42	9.19	8/4	Tillage.....	14.00	12.84
	Sod	8.36	7.80		Sod	12.97	10.87
	Difference..	5.06	1.39		Difference...	1.03	1.97
7/26	Tillage.....	11.93	8.84	8/7	Tillage.....	15.35	15.31
	Sod........	6.81	5.21		Sod........	9.72	7.61
	Difference..	5.12	3.63		Difference..	5.63	7.70

TABLE VIII.— *Continued.*

1907.				1908.			
Date.	Plat.	1-6 in.	6-12 in.	Date.	Plat.	1-6 in.	6-12 in.
		Per ct.	*Per ct.*			*Per ct.*	*Per ct.*
7/30	Tillage.....	11.69	9.84	8/11	Tillage.....	15.27	15.28
	Sod........	5.46	4.72		Sod........	10.08	8.02
	Difference..	6.23	5.12		Difference..	5.19	7.26
8/2	Tillage.....	13.20	10.92	8/14	Tillage.....	14.72	12.47
	Sod........	7.82	5.75		Sod........	11.70	8.10
	Difference..	5.38	5.17		Difference..	3.02	4.37
8/6	Tillage.....	10.64	10.72	8/18	Tillage.....	14.56	12.98
	Sod........	7.08	5.47		Sod........	14.07	12.71
	Difference..	3.56	5.25		Difference..	.49	.27
8/8	Tillage.....	10.02	10.15	8/21	Tillage.....	12.33	11.21
	Sod........	4.82	3.80		Sod........	8.70	7.81
	Difference..	5.20	6.35		Difference..	3.63	3.40
8/14	Tillage.....	11.79	9.62	8/25	Tillage.....	10.98	9.21
	Sod........	4.38	4.07		Sod........	6.39	6.08
	Difference..	7.41	5.55		Difference..	4.59	3.13
8/17	Tillage.....	9.37	9.07				
	Sod........	5.21	3.58				
	Difference..	4.16	5.49				
8/20	Tillage.....	8.56	8.18				
	Sod........	3.99	2.68				
	Difference..	4.57	5.50				

TABLE IX.

MOISTURE PER ACRE IN TILLED AND SOD PLATS.

Soil depth.	Plat.	1907. Amount of moisture.			1908. Amount of moisture.		
		Per ct.	*Tons.*	*Gallons.*	*Per ct.*	*Tons.*	*Gallons.*
1–6 in.	Tillage	12.20	109.80	26,330.9	14.04	126.36	30,302.1
	Sod	7.30	65.70	15,755.4	10.06	90.54	21,712.2
	Difference	4.90	44.10	10,575.5	3.98	35.82	8,589.9
1–12 in.	Tillage	11.53	152.64	36,604.2	13.57	181.17	43,446.0
	Sod	6.52	84.60	20,287.7	9.37	123.39	29,589.9
	Difference	5.01	68.04	16,316.5	4.20	57.78	13,856.1

These figures substantiate what all admit in regard to other crops; that, in this climate, conserve it and save it as best can be done, the seasonal rainfall on the average soil is not sufficient for the maximum development of the crop; indeed it is seldom sufficient for the optimum development of a crop. If then the rainfall is divided between two crops, grass and apples, one or both must suffer.

The actual difference between the moisture content of the two plats has been shown by Table VIII and, summarized, in Table IX. It is now purposed to show what part the grass plays in causing this difference. Obviously the grass requires water. Can it be shown that if this water had not been used in growing grass it would have been used for apple tree growth and in the production of apples?

Among others, Hellriegel and Wollny in Germany, Lawes and Gilbert in England, and King in Wisconsin, have published figures to show how many tons of water are required to produce one ton of dry matter in various crops. In Wisconsin King[8] found that "the amount of water used ranges

[8] Physics of Agriculture. By F. H. King, Madison, Wisconsin; 1901, p. 140.

from 270 tons with corn to 576 tons with clover per ton of dry matter." No figures are given for grass hay but that for clover is given above and for oats 503.9 tons and for barley 464.1 tons are given. We may assume, lacking definite figures, that a hay composed of orchard grass, timothy and blue grass would require as much as barley, the plant requiring the least water of the three plants having similar habits of growth given above, or 464.1 tons per ton of dry matter in the hay. Several competent farmers were asked to estimate the amount of hay per acre the sod plat of this experiment would produce. The lowest estimate was two tons (equal to 1.7 tons of dry matter) and this figure we shall take. (Plates XXV and XXVI give an idea of the stand of grass on the plat.) Assuming then that the two tons of grass grown on each acre of the plat require 689 tons of water we find that to make this amount of water per acre requires 6.32 inches of rainfall. Since the average rainfall in this region for the six growing months, as shown in Table X, is but 17.78 inches there are but 11.46 inches left for apples and to provide for evaporation, the surface run-off and for subterranean drainage.

TABLE X.— AVERAGE RAINFALL FOR THE GROWING MONTHS AT ROCHESTER — AUCHTER ORCHARD SEVEN MILES DISTANT.

Years.	April.	May.	June.	July.	Aug.	Sept.	Totals.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1884	0.83	2.49	2.01	2.33	1.44	3.17	......
1885	1.26	1.58	2.49	4.64	5.02	2.11	......
1886	4.13	1.92	2.92	4.41	2.86	2.31	......
1887	1.37	0.46	2.01	6.37	3.03	0.75	......
1888	3.09	2.79	3.88	0.99	4.02	2.73	......
1889	3.28	1.21	7.47	4.57	4.98	2.50	......
1890	2.20	5.49	5.26	1.07	4.34	5.81	......
1891	1.63	0.49	4.31	3.52	3.16	0.47	......
1892	0.67	4.04	3.95	1.89	4.77	1.12	......
1893	2.59	4.92	3.08	3.68	5.38	2.68	......
1894	2.43	7.03	1.77	1.50	1.22	4.64	......
1895	1.33	2.88	2.93	2.90	2.66	0.94	......
1896	0.41	2.31	3.71	4.12	3.33	4.27	......
1897	1.90	2.19	3.16	5.28	1.27	2.36	......
1898	2.03	1.90	2.39	1.32	3.60	1.86	......

TABLE X.— *Continued.*

Years.	April.	May.	June.	July.	Aug.	Sept.	Totals.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
1899	1.12	1.69	1.71	4.15	1.05	2.23	......
1900	0.95	1.71	1.45	6.53	1.75	0.91	......
1901	4.43	3.80	2.07	3.97	5.62	2.46	......
1902	1.92	2.84	4.33	5.25	2.41	2.88	......
1903	2.60	0.23	7.77	4.86	7.21	1.30	......
1904	1.67	4.04	3.37	5.73	2.56	3.26	......
1905	2.05	2.01	8.78	3.39	5.44	1.90	......
1906	2.08	4.24	5.31	2.37	3.68	2.16	......
1907	2.42	1.82	2.34	2.86	1.35	2.73	......
1908	3.28	3.57	1.96	4.72	1.79	1.66	......
Average for 25 years	2.06	2.70	3.61	3.69	3.35	2.37	17.78
Average for 5 years — 1904 to 1908	2.30	3.13	4.35	3.81	2.96	2.34	19.89

Let us now consider the disposition of the 11.46 inches of rainfall that remains after the grass has had its supply. We have no data for this piece of land as to the amount of surface evaporation, run-off, and subterranean percolation. But using figures somewhat below the average as obtained by soil physicists in various experiments we may put the evaporation at 4 inches of rainfall, the run-off at 1 inch and the downward seepage at 1 inch, leaving 5.46 inches for the apple tree and its crop. But few data are at hand as to the water requirements of apples but since the apple plant begins growing early and continues until late fall, since it has an enormous leaf surface and a relatively large number of stomata, and since the yield of fruit is six tons or more to the acre, it may be assumed that the apple needs a large amount of water. This assumption is supported by the work of Loughridge[9] in California who found that of the apricot, olive, peach, citrus fruits, fig, almond, plum, grape and apple among fruits the last is least resistant to drought, requiring three times as much water as the apricot, olive or peach; twice as much as the citrus fruits or fig, one and a half times as much as the almond and plum; and one and one fifth times as much as the grape. These considerations must

[9] Cal. Exp. Sta. Rpt., 1897–98: 95.

lead to the conclusion that the 5.46 inches of rainfall left after the grass has taken its share of water and the natural waste has taken place, is not nearly enough to enable the apple to make an optimum growth or produce an optimum crop. It should be noted, too, that grass makes its heaviest demands for moisture at the time when the trees need the water most.

The conclusion that the differences in tree growth and crop in the two plants of this experiment are mainly due to differences in moisture, are in accord with the teachings of the best authorities on soils in this country. Thus King states:[10] "There are very few fields upon which crops of any kind, in any climate, can be brought to maturity with the maximum yields the soils are capable of producing without adopting means of saving the soil moisture." Hilgard[11] holds that "under ordinary conditions of culture, and within limits varying for different soils and crops, production is almost directly proportional to the water supply during the period of active vegetation." Whitney[12] claims that the moisture supply in the soil is the only important factor to be regulated by the cultivator in most soils, all other factors being, in general, provided for naturally. A generation ago Johnson[13] wrote: "It is a well recognized fact that the next to temperature, the water supply is the most influential factor in the product of a crop. Poor soils give good crops in seasons of plentiful and well distributed rain or when skillfully irrigated, but insufficient moisture in the soil is an evil that no supplies of plant-food can neutralize."

Table X shows that the average rainfall for the five years of this experiment is 2.11 inches more than the average for the 25 years of which it is a part. Thus the period has been favorable for the sod-mulch method.

[10] Physics of Agriculture. By F. H. King. Madison, Wisconsin: 1901, p. 181.

[11] Soils. By E. W. Hilgard. New York: 1906, p. 193.

[12] U. S. Dept. Agr., Bureau of Soils, Bul. 22. 1903.

[13] How Crops Feed. By Samuel W. Johnson. New York: 1870, p. 216.

The food supply.—A consequence of the reduced water supply in the sod plat is, of course, a reduced food supply; for it is only through the medium of the free water in the soil that plants can take plant-food. Food, then, because of the greater supply of water, is more available in the tilled plat than in the sod plat. Beyond this statement, data at hand do not permit us to go. Table XI shows analyses of composites of soil taken from different parts of the two plats early, mid-season and late in the season of 1908. The differences are slight and variable and mean, if any thing, that the differences in water soluble plant-food in the two plats are too small to be detected by chemical analyses.

TABLE XI.—WATER-SOLUBLE PLANT-FOOD IN THE SOD AND TILLED PLATS OF THE AUCHTER ORCHARD.

Season.	Depth.	Plat.	Soluble matter.	Organic matter.	Potash.	Phosphoric acid.	Nitrogen.
	In.		*P. p.m.	*P. p.m.	*P. p.m.	*P. p. m.	*P. p.m.
Early	6	Sod	321.6	141.2	12.8	3.6	10.8
		Tillage	303.2	143.6	7.6	2.8	11.2
		Difference	18.4	-2.4	5.2	.8	—.4
Mid-season	6	Sod	217.2	81.2	8.8	2.8	5.2
		Tillage	278.0	121.6	7.2	2.4	5.2
		Difference	—60.8	—40.4	1.6	.4	0.0
Late	6	Sod	237.6	102.8	12.8	3.6	3.6
		Tillage	267.6	116.0	4.8	2.4	11.6
		Difference	—30.0	—13.2	8.0	1.2	—8.0
Early	12	Sod	240.0	119.2	7.6	2.0	19.2
		Tillage	158.0	100.0	4.0	1.8	11.6
		Difference	82.0	19.2	3.6	.2	7.6
Mid-season	12	Sod	272.8	139.2	4.8	2.8	22.0
		Tillage	166.4	110.0	3.6	1.4	13.6
		Difference	106.4	29.2	1.2	1.4	8.4
Late	12	Sod	121.2	49.6	3.6	2.4	6.8
		Tillage	130.4	57.6	3.2	1.8	4.8
		Difference	—9.2	—8.0	.4	.6	2.0

*Parts per millon.

PLATE XXIX.— ROOTS ENTERING TILLED PLAT FROM SOD.
Twenty Feet from Tree.

PLATE XXX.— ROOTS THIRTY TO FORTY FEET LONG PASSING UNDER STONE WALL BETWEEN SOD PLAT AND LANE.

Plate XXXI.—Stone Wall Bordering Sod Plat.
Trees and Fruit near this Wall were Much Better than in Interior of Plat.

There is much to show that there is an abundance of plant-food of all kinds in both plats of this experiment. The trees in the tilled plat showed, in all respects, good feeding and such trees in the sod plat as could get any considerable portion of their roots into the tilled plat, or the adjoining tilled fields, likewise seemed to be well fed. Moreover the fertilizers added to certain rows in each plat, as described on page 452 give no appreciable results in either plat. Another strong proof of the high degree of the fertility of the land is the growth of grass it produces. It would be hard to find, in or out of an orchard, a better stand of orchard grass than that annually produced on the sod plat of this experiment.

There should be little difference in the amounts of the several plant foods in the two plats, if, as may be assumed, they contained the same amounts at the beginning of the experiment, for only the crop of apples has been taken from either plat. Table XI seems to show that there is a little more potash, phosphoric acid and nitrogen in the sod plat than in the tilled one. The differences are so slight as to be quite within the range of variation yet it may be that they come from the fact that the tilled trees have made a much greater growth and have produced much larger crops than those in sod and thus have used more food.

If lack of food is the cause of the deleterious effect of the sod on the trees it is starvation in the midst of abundance. The food is in the soil but because of a lack of water to bring it into solution, or because the soluble fertility is monopolized by the grass, the trees do not get it. The fact that the grass does not seemingly suffer suggests that the grass roots surround the tree roots and have the first opportunity to take moisture and food and leave but little for the rootlets of the trees.

The last consideration suggests that in deep, fertile soils where the tree roots may go down and escape the grass roots, competition between the two plants may be less strenuous and the effect of the grass on the apple therefore less harmful than in the comparatively shallow soil of the Auchter orchard.

The data given on page 441 show that the orchard soils of New York are shallow. In 333 orchards out of 528 in this State the top-soil is not over twelve inches deep. The average depth of the top-soil in the Auchter orchard is, as we have seen, from nine to twelve inches. Since the rooting habits of trees are very different, sod may be more harmful to some varieties than to others.

There is more humus in the tilled plat than in the sodded plat.— Humus has numerous and important functions in the soil for vegetable growth. The advocates of sod for orchards urge as one of their strongest arguments that tillage "burns" out the humus. It is granted at once that tillage without cover crops, green manure crops or the addition of stable manure or other organic matter, does decrease the humus content. But such tillage is now seldom practiced or advocated. Farmer and fruit-grower know well that for any series of crops or on any soil organic matter must be supplied; and experiment stations and horticultural press have for years been urging green manure crops and cover crops as supplements to the dressings of stable manure which are applied at greater or less intervals in all commercial orchards.

The advocates of the sod-mulch methods have offered no data to show that in mulched orchards in grass there is more humus than in tilled orchards in which cover crops or green manure crops have been used. This experiment furnishes some data to show that tillage and cover crops supply trees with even more humus than they get in sod with the gross cut as a mulch.

TABLE XII.— HUMUS PER ACRE IN SOD AND TILLED PLATS AT DEPTH OF SIX INCHES.

		Per ct.		Per ct.
July	Tillage	2.32	Sod	2.19
August 25	Tillage	2.53	Sod	2.25
Average		2.42		2.22

Gain for tillage, .20 per ct.
Gain in tons per acre, 1.8.

Table XII shows that there is 1.8 tons per acre half-foot more humus in the tilled plat than in the sodded plat of this experiment.

But little is known about the value of humus for fruit soils. Some of the best orchards in the arid regions of the West have almost no humus. Nor are the functions of humus well known. It can hardly be held, therefore, that the slight excess of humus in the tilled plat of this experiment has made any great difference in either tree growth or crop. The data given are offered as a contribution to the knowledge on the subject and to offset the oftmade assertion, unsupported as yet by evidence, that the tillage method of managing an orchard " burns out the humus."

The temperature of the soil is lower in the sodded land.— The great importance of a proper soil temperature is recognized by all who grow plants. The florist and gardener want more or less " bottom heat " for all the plants they grow and the farmer and fruit grower shun cold soils for all of their crops. It is scarcely probable that in this climate, if there be an abundance of moisture, any of our soils ever become too warm for any crop. While, then, no data can be set forth to show that the apple will do better in a warm soil than in a cold soil, these general considerations would lead any apple-grower to choose a warm soil, and would lead him to prefer, other things being equal, a method of soil management which gives him the warmest soil.

TABLE XIII.— SOIL TEMPERATURE IN TILLED AND SODDED LAND.

Date.	Depth of 6 inches.				Depth of 12 inches.				Weather conditions.
	A. M.		P. M.		A. M.		P. M.		
	Sod.	Tilled.	Sod.	Tilled.	Sod.	Tilled.	Sod.	Tilled.	
6/28....	62	71½	63	72½	63	63½	63½	65½	Bright.
6/29....	65½	66¼	67	68	63¼	65¾	63	65¼	Rainy.
7/1.....	61½	61¾	70	70	61	62	62¾	64	Very cloudy.
7/2.....	66	66	65½	65	63½	64½	63¾	63½	Very cloudy.
7/3.....	60½	59½	69	69½	61¼	61½	62½	63½	Bright.
7/4.....	62¼	62	68	70	62	63	63	65	Bright.
7/5.....	63½	63¾	71¼	72½	62½	64	63¾	65½	Slightly cloudy.
7/6.....	64½	65	70¾	72	63¼	65	63¾	65½	Cloudy.
7/8.....	67	68	70¾	72¾	65	67½	65	67½	Cloudy.
7/9.....	66½	67½	73	75	64½	67	65½	68	Bright.
7/10....	66	67	72½	74½	64¾	67¼	65½	68	Slightly cloudy.
7/11....	66½	68	67	68	65	67½	63	64	Rainy.
7/12....	63½	64	68	68	62¾	64½	64	66	Bright.
7/13....	62¾	62½	70¼	70¼	62¾	63½	64	65	Bright.
7/15....	66½	67	73¼	75	64¾	66¼	65¾	67¼	Slightly cloudy.
7/16....	69	70	75½	77	66	68	67½	69¾	Slightly cloudy.
7/17....	70¼	71¼	75½	77½	57½	69½	68¼	70½	Cloudy.
7/18....	70½	71½	73¾	75	67½	69¾	67½	69¾	Slightly cloudy.
7/19....	69	70¼	76	77½	67½	70	68½	71	Bright.
7/20....	70¾	72	73	73½	68	70¾	68½	70¾	Bright.
7/22....	69	76	71¼	72½	67	69¼	66½	68¼	Rainy.
7/23....	68	68¾	73¼	74	67½	68¼	67¼	69	Cloudy.
7/24....	68	68¼	71	71¼	66¾	68½	66½	68¼	Bright.
7/25....	67½	68¼	73¼	73¾	66½	68	67½	68½	Bright.
7/26....	67¾	68¼	73½	73¼	66½	68	67½	69	Slightly cloudy.
7/27....	69	69½	70¾	70	67	69	66¾	68½	Slightly cloudy.
7/29....	67	67¾	73	73½	65½	67½	66½	68½	Slightly cloudy.
Aver..	66.3	67.4	71	73.3	64.5	66.6	65.4	67.2	

Table XIII shows that the tilled soil is warmer morning and night at depths of six inches and twelve inches than is the sodded soil. At the first named depth the tilled soil is 1.1° warmer at seven o'clock in the morning and 1.7° warmer at six at night. At a depth of twelve inches the tilled soil is 2.3° warmer at the morning hour and 1.8° in the evening. These results agree with the experimental results and conclusions of the best soil authorities. For example, Hilgard says:[14] "A cover of either living or dead vegetation depresses the temperature of the soil as compared with the bare land, as elaborately shown by Wollny and Elbermeyer. In the monthly averages these differences rarely exceed .8° C. (1.5°

[14] Soils. By E. W. Hilgard. New York: 1906, p. 305.

F.), and are mostly below .50° C. (1° F.), but during different parts of the day they may rise to 2.2 to 2.5° C. (4 to 4.5° F.), at 4 inches depth."

Criticisms of the data may be made and these we hasten to anticipate. It is possible that the differences between the tilled and the sodded plats would be reversed at night, as the tilled soil probably would lose more heat by radiation and diffusion. Such differences, we think, would be more than offset by temperatures taken at the hottest part of the day. The table, it is now seen, is defective in not having midday and midnight observations. An examination of the data shows that on some days the differences are large, on others small and on still others they are reversed. These variations may be due to differences in the air temperature which, when high, would give a high tilled-soil temperature; sunshine would cause a similar rise in the heat of the tilled soil; dry air would cause great evaporation from the grass and a consequent low temperature beneath it; and windiness might affect the readings one way or the other.

How important this difference in temperature is, cannot be said with our present knowledge on the subject. But a consideration of the ways in which a high temperature influences vegetable growth will lead to the conclusion that even a slight increase in temperature may be helpful to the apple. King[15] gives the following ways in which a high soil temperature aids in plant growth: Heat hastens the solution of food substances; it makes the diffusion of dissolved substances more rapid; it is more conducive to rapid and thorough soil ventilation; it develops stronger osmotic pressure thereby forcing the soil solutions into the roots and upward mre rapidly; and lastly it hastens the formation of nitrates. As regards the formation of nitrates King says:[16] "In studying the conditions under which the nitric ferment works most vigorously, it has been learned that the germs cease to develop nitric acid from humus

[15] The Soil. By F. H. King. New York: 1895, pp. 221–225.
[16] Ib., p. 224.

when the temperature falls below 41° F.; that its action is only appreciable at 54° F., while it becomes most vigorous at 98° F., but that at 113° F. its activity drops back again to what it was at 59° F. Here, again, is another and very urgent need for the right soil temperature." The augmentation of any one of the processes named above is of importance, and all taken together make certain that any condition which raises the soil temperature must very greatly accelerate vegetative activity and thus become of practical importance.

The aeration is better in the tilled soil.—The fact stated in the heading of this paragraph is so obvious as to hardly need discussion. To *till* is to stir and loosen the soil. When soil-granules are massed loosely, as in a tilled field, unoccupied space exists between the granules and this space permits the free movement of air. If the granules are packed together tightly, as in sod land where the soil cannot be loosened, there is comparatively little unoccupied space between granules for the movement of air. All sod land, as compared with that under tillage, is poorly aerated, and in most cases the older the sod, the less well ventilated, for as time passes the soil granules are more closely packed by the elements and the roots of the grass. The ideal soil is often compared to a sponge, not only because of its capacity to hold nutritive solutions but because of permeability for air. Hilgard[17] says in this connection "there can be no question that the higher productiveness of well-cultivated soils is largely due to the greater and readier access of air to the roots."

The functions of air in the soil are discussed in all text books on soils and need be only briefly mentioned here. Air insures the presence of both oxygen and carbonic acid in the soil. Oxygen is the "vital air" of plants as of animals — absolutely necessary to life; it is necessary, too, in all decays, fermentations, putrefactions, and nitrifications and without it there could be no beneficial soil micro-flora. Carbonic acid plays an

[17] Soils. By E. W. Hilgard. New York: 1906, p. 279.

important and indispensable part in bringing inorganic materials into solution for plant food.

While no data can be given from this experiment to show that the soil of the tilled plat is better aerated than that of the sodded plat, or for that matter that aeration is necessary to the apple, yet the above considerations, necessarily very brief, are convincing as regards both points. We are justified, without the presentation of specific data, in saying that the better growth and greater productiveness of the tilled trees are in some degree, and probably no small one, due to the better aeration of the tilled soil.

The beneficial micro-flora is larger and more active in a tilled soil.—No experimental evidence is offered to show that the flora of micro-organisms is larger in the tilled plat of this experiment than in the sodded plat. Such evidence is not necessary, for experimenters in this field are well agreed that beneficial micro-organisms are found in greater numbers and are better distributed in a cultivated soil than in compact and uncultivated soils. These lower forms of life, as with higher forms, are profoundly affected, both as to their individual well being and as to their multiplication, by such environmental conditions as food, air, moisture and temperature, all of which factors are better regulated for all growth by cultivation. One of the objects of tillage, as set forth in the latest agricultural text-books, is to convert the soil into a suitable living place for micro-organisms through the increase of humus, good drainage, good ventilation, and a higher temperature. It is not unreasonable, therefore, to assume, though specific data are wanting, that the greater number and better condition of the micro-organisms in the tilled plat of this experiment contributed to the greater well being of the trees thereon.

The toxin theory.—There is much evidence to show that all plants, to a greater or less degree, so change the soil in which they grow as to make it wholly or practically unfit for a succeeding crop of the same kind. There is evidence to show,

too, that, somehow, different crops growing in the same soil may injure each other or the one the other. Two theories are advanced to explain these antagonisms of plants. One is that plants excrete toxins; the other is that the injurious effect arises from the action of bacteria or from the injurious products of bacteria brought about by some interaction between the higher plants and the micro-flora.

Pickering, of the Woburn Farm, in accounting for the injurious effect of grass upon the apple, as we have seen,[18] does not attribute the harm done to the competition for moisture and food, to a difference in temperature, to a lack of air and oxygen or to excessive amounts of carbon dioxid, but holds that it is due to some "actively malignant effect on the tree, some action on it akin to direct poisoning." More recently the same experimenter leaves the question open as to whether the harmful action is due to toxin from the roots of the grass or to some change in the activity or product of the micro-flora brought about by the sod.

Beside this specific experiment with the apple and grass there have been several investigations with other plants to show that vegetable organisms have interdependence other than those with their physical environment. The Bureau of Soils of the United States Department of Agriculture has published a series of interesting investigations bearing upon the problem of plant excretions.[19] Hunt and Cates[20] show in a bulletin of the Cornell Agricultural Experiment Station an antagonistic effect between corn and weeds. Studies on the effect of weeds in corn made by Dr. Sturtevant[21] at this Station in 1883, 1884 and 1886, show this antagonism, although the cause of the malign influence was not assigned to toxicity. At the second annual meeting of the Society for Horticultural Science the writer read a paper[22] on "The Relationship of Plants" in

[18] See page 445.
[19] U. S. Dept. Agr., Bureau of Soils, Buls. 22, 28, 36, 40 and 47.
[20] New York Cornell Exp. Sta. Bul. 247:188.
[21] Ann. Repts. of this Station, 1883:137; 1884:100, and 1886:50.
[22] Proceedings of the Society for Horticultural Science. 1905:72.

which investigations with peaches grown in pots with several other plants show that the peach does not thrive if its roots are in close proximity to those of certain other plants.

As has been described on page 468 apple roots escape at every opportunity from the grass roots, establishing, where nearby tilled or sodless soil permits, a veritable "dead line" between apples and grass. The extremely deleterious effect of the grass roots on the apple, and the extreme sensitiveness of the apple roots to grass roots, curving away from them as if they had perceptive organs, suggests that there may be an unknown factor partly responsible for the effects of grass on apples. In this respect, however, this experiment is not crucial and it is best for the present to attribute the injurious action of the grass in the main to known factors — to disturbances of plant nutrition, leaving the more obscure factor until further evidence is secured.

APPLICATION OF RESULTS.

The well being of nearly all the plants which minister to the needs of man is improved by tillage. It does not appear from this experiment that the apple is an exception. This fruit responds to high cultivation in the nursery row; it seems to continue to do so when transplanted to the orchard. Results as positive as in this experiment can be made very comprehensive. They will, it is believed, apply to all varieties of apples, and to all fruits, for that matter, and to practically all fruit soils and conditions. It should not be expected, however, that sod will be deleterious in the same degree under all conditions. It should be expected, for instance, that in a deep soil, where the apple roots can escape from the grass roots, or in one containing a great amount of soil moisture, the harmful effects of the grass will not be so marked as otherwise. The experiment does not show that apples can not be grown in sod. There are many orchards in New York which would prove the contrary. It suggests, however, that apples thrive in sod, not because of the sod, but in spite of it. The fact that there are many

thrifty orchards in sod in New York is not proof that these orchards would not do better under tillage.

In considering the two methods of management, of all the factors affecting the growth of trees in this experiment, conservation of moisture should receive first attention from the apple grower. This statement is affirmed not only by the results in the Auchter orchard but in practice the world over. The climate of Europe is moist; sod orchards are the rule there. Near the Atlantic seaboard in America, as in New England, where the rainfall is comparatively high, thrifty orchards are found in sod. In the western fruit regions where irrigation is practiced, sod orchards are hardly to be found; water is purchased and must be conserved. In irrigated lands tillage is found to be the best means of moisture conservation. Moisture is by no means the only factor to be considered in the controversy over the sod and tillage methods of management, but it appears to be the chief one.

The statement is often made that trees will become "adapted" to grass. There is nothing in this experiment to indicate that such is the case. The sodded trees began to show ill-effects the first year the orchard was laid down to grass and each succeeding year has seen greater injury. Trees can hardly become adapted to thirst, starvation, asphyxiation and poison.

To manage the soil of an orchard properly requires nice adjustments and delicate balancing for each particular case. Soils vary much and all are complex; quite diverse chemical, physical and biological changes take place in diverse soils. Every apple-grower, therefore, has a problem of his own. But the individual problem can be best solved by the rational application of the ordinary laws of nutrition and growth—those which apply to cultivated plants in general. The apple is not unique among plants.

THE GRAPE DISTRICTS OF NEW YORK AND TABLE OF VARIETIES.*

M. J. DORSEY

INTRODUCTION.

The basis of this bulletin is "The Grapes of New York," prepared by this Station and published by the State Department of Agriculture. In collecting the material for the grape book, much valuable information was contributed by the grape-growers of New York in co-operation with the Station. The edition of the larger work was necessarily limited. It is the purpose of this bulletin to place before the grape-growers an accurate summary of the information contained in the grape book.

The bulletin contains: First, a discussion of the natural factors influencing grape culture. Second, an account of the location, soil, climate, history and present status of the four great grape districts of New York. Third, a brief description of the most important species of Vitis, giving their natural habitat, botanical differences and horticultural importance, with the object of showing their significance in varieties. Fourth, a table of 161 of the most important varieties, giving the species, fruit and vine characters, date and place of origin or introduction, and a brief statement of their value for the grower.

THE NATURAL FACTORS INFLUENCING GRAPE CULTURE.

Commercial grape growing in New York is practically confined to four well-defined and specialized districts. This is largely due to the favorable influence of the natural factors

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which govern the distribution of plants. Few species are more decidely influenced than the culivated grape by latitude and altitude, temperature, water supply, air currents, the chemical and physical properties of the soil, insects and fungi,— the natural factors which determine local environment.

Altitude and latitude.— The temperature of a place, as well as the amount of sunlight and the length of the growing season, is largely determined by the latitude and altitude. Local modifications often counteract these. In general, cultivated varieties are more exacting in their demands than native species; because such plants are usually removed from their natural habitat, and their growth attempted in places having a different elevation, a longer or shorter growing season, or a higher or lower annual temperature. Similar susceptibility to environmental variations is also shown in the case of grapes from crosses between species long adapted to different climatic conditions.

Temperature.— The grape requires a relatively even air temperature: In the latitude of New York, regions and seasons having a comparatively low temperature during the growing season of May, June and July, with much sunshine during the maturing months of August, September and October, produce the best grapes. Grape growing is perhaps dominated more by air temperature than any other single factor. This largely determines the northern range and hardiness of varieties, which ones can be grown successfully in any region, and in many seasons where and when there shall be a crop. Its influence is seen at different periods of the year in winter killing, damage by late spring or early frosts, shrivelling and drying up of the leaves or sunscald of the fruit. In the control of air temperature lies the value to the grape of large bodies of water, like lakes and wide rivers, which temper the cold winter and hot summer weather, equalize night and day temperatures and lengthen the growing season by warding off frosts in the spring and autumn.

Water.— Not only must the total annual rainfall be considered but also its distribution throughout the season. The smallest quantity required for a good vine growth produces the best crops, freest from diseases. An excessive rainfall during the growing and maturing season favors the growth of fungi, checks and weakens root development while at the same time it induces too great a growth of vine and when coming at blooming time hinders the proper setting of fruit. A comparatively dry soil favors a larger root growth which is better able to stand drouth, and is less favorable to fungus diseases, but more favorable to the phylloxera. Species and varieties differ as to their ability to withstand an excess of moisture.

Air currents.— Air currents and air drainage are of most importance in the control or suppression of fungi. In regions having good air drainage the dreaded black-rot and mildew are less destructive. When the temperature is near the freezing point, winds or air drainage often keep the air in motion and prevent frosts. On the contrary, winds, when dry, strong or cold, unless modified by windbreaks or physical features may prove to be detrimental in their effects upon vineyards.

The soil.— Fertility, the physical characters and conditions and soil heat are important factors in determining the suitability of a soil for grape-growing.

Great natural fertility is unnecessary. Soils too rich produce an overdevelopment of the vine at the expense of hardiness and fruitfulness. Some species grow naturally upon poor light soils. Fertilizers, and especially cover crops and stable manure, can be used to supply very largely a natural lack of fertility.

The grape is influenced more by the physical character of the soil than by fertility. The two distinct types of soils in agricultural regions are sand and clay; the soil takes the characters of the one which predominates. These two types produce a similar growth of vine, but have a different influence upon the quantity and quality of the fruit. As compared with the sandy soil, the clay is more compact, more retentive of

moisture, and cooler. Grapes prefer a light friable soil to one more compact. Lightness and friability can be increased by cultivation and sub-soiling or by the use of cover crops and stable manures. A suitable condition of the soil should precede the planting of a vineyard.

The preference which a number of varieties show for sands, loams, shales and gravels depends largely upon the heat found in such soils. The farther north, or the longer the season required for ripening, the greater becomes the necessity for a warm soil. Soil heat can be influenced by drainage, by the addition of humus, or by cultivation. The grape is no more exacting as to soil requirements than other fruits, but the necessity of selecting a suitable soil, coupled with favorable climatic conditions for its commercial culture, needs no stronger argument than the fact that in New York we have the viticulture of the State centered in four comparatively small districts, while commercial success with the grape appears to be impossible on much larger areas which produce good crops of other products, even fruits.

Insects and fungi.— Since the advent of spraying and a more accurate knowledge of the life cycles of insects and fungi, their ravages have become more and more within the control of man and their influence upon grape-growing of less importance, and there are some favored vineyards in which neither insects nor fungi are troublesome. Nevertheless, instances where promising viticultural ventures have been wiped out of existence, or survive only as a result of constant and expensive combative measures, still place insects and fungi as factors requiring careful consideration.

GRAPE DISTRICTS OF NEW YORK STATE.

THE CHAUTAUQUA DISTRICT.

The Chautauqua grape belt extends along the southeastern shore of Lake Erie, averaging about three miles in width, and is about fifty miles long. It lies in Erie and Chautauqua counties; its northeastern boundary is not far from the Erie-

Chautauqua line; its western limit is an arbitrary division — the New York-Pennsylvania line — for the district passes into Pennsylvania.

Elijah Fay planted the first grapes in this district in 1818; they were wild vines of *Vitis labrusca* from New England. In 1822 he planted roots of Millers Burgundy, Sweetwater and Black Hamburg. These were not as successful as the first, and the real start was made in 1824 when Mr. Fay planted Catawba and Isabella vines secured from Prince of Long Island. These vines were trained on trellises and covered an area two by eight rods in extent. The sale of grape vines was started by Lincoln Fay in 1834; but few were sold, for in 1859 there were only twenty acres of bearing vines in the town of Portland. In the decade following, the Concord was introduced, and in 1870 there were about 600 acres in Chautauqua County. The first carload of grapes was shipped from Chautauqua County in 1880; the shipment was made to Philadelphia by Jonas Martin. In 1900 the shipment reached 8,000 carloads and in 1906, 5,634 carloads. This apparent decrease is accounted for by the large quantities used locally for wine and grape juice. According to a canvass made by this Station in the preparation of "The Grapes of New York" the acreage of this district was, in 1906–7, distributed approximately as follows: Portland, 9,500; Westfield, 5,700; Ripley, 5,700; Pomfret, 4,600; Hanover, 1,950; Sheridan, 1,950; Dunkirk, 600; making a total of about 30,000 acres of grapes. According to the figures gathered 90 per ct. of this acreage was set to Concord, 3 per ct. to Niagara, 2 per ct. to Worden, 1 per ct. each to Moore Early and Catawba, with the remainder made up of a dozen or more varieties, of which Delaware leads.

The grape belt proper is on a comparatively low, narrow plain, bordering the southeastern shore of Lake Erie and extending back from the lake bluff to the bill or escarpment, which rises from 500 to 700 feet above the plain and 500 to 1,000 above the lake. The plain is gently rolling and everywhere may be seen ancient beach lines, ascending in from two

to five well defined terraces which rise above the lake bluff with a grade of from one to two hundred feet to the mile. The plain, the terraces, and the escarpment form the chief natural topographical features of the district.

The soils, as mapped by the Bureau of Soils of the United States Department of Agriculture, are Dunkirk clay, Dunkirk gravel, Dunkirk gravelly loam, Dunkirk sandy loam and Dunkirk shale loam. Back from the lake east and west from Barcelona, in the region of Van Buren, and about Dunkirk, are found the largest areas of Dunkirk clay, which ranges from a few inches to a foot in depth, resting upon a stiffer and more tenacious clay. It was upon the Dunkirk gravel, which is found upon the terraces at the foot of the "hill," that grapes were first grown. This soil is a week or more earlier than other soils and is largely planted to early varieties. The Dunkirk gravelly loam runs practically the whole length of the belt at the base or on top of the gravel ridges and is underlaid at a depth of about three feet with sand and shale fragments. This soil produces a growth similar to that on the gravels, though with some varieties it is claimed the berries are larger and with other the amount of wood is greater. The largest areas of Dunkirk sandy loams occur east and west of Dunkirk and Fredonia, bordering the lake in large irregular areas or extending back from the bluff to the escarpment. Other areas occur about Brocton and Portland and smaller ones east of Barcelona and northwest of Ripley. This soil is brownish yellow, is found on undulating land, ranges from six to twelve inches in depth, and produces good crops. The Dunkirk shale loams are found upon the escarpment and are furthest from the lake. The soil is thin, brown in color, has considerable shale on the surface and is underlaid with heavy clay. Grapes from this soil are high in flavor, contain a good amount of sugar, mature early, and are much sought for in making wine.

The climatic conditions of the Chautauqua district are especially favorable. The high escarpment running its whole

length confines the lake influence to a narrow space, tempering the inshore breezes of the day and off-shore breezes of the night. These keep the air in nearly constant motion, averting frosts in spring and autumn and preventing the formation of heavy dews and fogs.

The Chautauqua district has a system of pruning and training peculiar to itself. Posts six to eight feet in height are set every third vine, with two wires running through the row; the lower one 28–32 inches above the ground and the upper 22–36 inches above the first, each varying in height according to the size or age of the vine. The arms are tied to the lower wire and the canes and shoots to the upper. Cultivation varies greatly but is thorough by the best growers. Spraying is not generally practiced owing to the freedom of the district from pests.

THE CENTRAL LAKES DISTRICT.

The Central Lakes district is made up chiefly of three distinct localities about Keuka, Canandaigua and Seneca Lakes, though the vineyards of this region are in the five counties of Ontario, Yates, Schuyler, Steuben and Seneca. Vineyards surround Keuka Lake in Yates and Steuben counties, the southern half of Seneca, and all except the lower end of Canandaigua Lake. There are less extensive plantings about Naples, Bath and Romulus. The soil, climate, varieties and methods of culture are so similar in all these areas that they can easily be grouped into one district.

Unlike the first attempts in the Chautauqua district, the first plantings made in this district at Hammondsport, in 1836, by Rev. William Bostwick, were successful. The varieties were Isabella and Catawba. Scattered plantings in gardens about Keuka followed this attempt. In 1853 Andrew Reisinger, a German vine-dresser, planted a commercial vineyard of two acres of Isabellas and Catawbas at Harmonyville. Two years later Hon. Jacob Larrowe and Mr. Orlando Shephard planted small vineyards of the same varieties in Pleasant Valley near

Hammondsport, and were so successful that they increased their plantings in 1858. Their example was soon followed by others and in 1860, 200 acres were set in Pleasant Valley alone, with large plantings in other places about Keuka Lake. The first plantings were made on the Yates side of Keuka Lake in 1855 when Mr. W. W. Shirland set a small vineyard to Isabellas. The first plantings about Canandaigua and Seneca lakes seem to have resulted from the spreading of the industry from the Keuka region. The dates and places of the first plantings are not known but there is evidence of plantings about Avon before those in Pleasant Valley. Mr. J. W. Prentiss made the first commercial shipment from this region in 1854, when he sent a ton of Isabellas, packed in tubs, to New York. A second ton sent by him "broke" the New York market. The Concord and Delaware were introduced into this region the same year; the first was introduced by John Mead, of the town of Benton, and the latter by Henry Rose of Penn Yan. Wine-making began about 1860 and the manufacture of wine, brandy, and champagne, has since developed into an important industry. About twenty-five companies are now found mostly centered about Keuka Lake. The acreage of the several counties in this region is estimated as follows: Yates, 7,940; Steuben, 5,570; Ontario, 2,630; Schuyler, 1,014; Seneca, 1,540; making a total of 18,694 acres. The principal varieties grown in this region are Catawba, Concord, Delaware and Niagara.

The topography of the region is more or less rough and broken; steep hillsides of the lakes formed both by erosion and tilting of the land, ranges of hills, and moraine deposits all combine to give character to the district.

Deep narrow lakes, occupying what are generally agreed to be preglacial valleys, temper the climate so that it is much less severe than in adjacent territory. Seneca Lake is so deep and its water so slow in cooling, that it has been known to freeze over only a few times in a century. Ranges of hills protect enclosed valleys. The high banks of the lakes protect the vineyards along the lakeward slopes from winds while the water

from the lakes equalizes the night and day temperatures during the growing season, preventing frosts and severe winter freezing. These influences, acting together, give to this district a long range of season, which ripens grapes one to two weeks earlier than in the Chautauqua belt.

The soils of this district, being of glacial origin, vary much in composition and texture; though in general nearly all of the grape soils of the Chautauqua district are to be found, with probably the Dunkirk clay loam predominating. In many places along the lakeward slopes, on the hills and moraines, the land is rough and stony with a thin covering of soil.

Different methods of pruning and training are used, but the high renewal system is used by most growers. In this system a trellis having three wires is used; the first is about 20 inches above the ground, with the others placed above it at intervals of 18 inches on the posts. The head of the trunk is twenty to thirty inches high above ground. New canes are brought out from renewal stubs or the head of the main trunk and tied to the wires above. This system is well adapted to the vine growth of the Catawba and Delaware. Thorough cultivation is practiced and fall cover crops are coming into favor. Insects are less troublesome and fungi more so in this district than in the Chautauqua district.

THE HUDSON RIVER DISTRICT.

The grape region along the Hudson River forms the third largest district of New York. The vineyards are, for the most part, found in Orange, Ulster, Dutchess and Columbia counties.

The first plantings in this district were made at Croton Point, in 1827, by Robert Underhill and his two sons, R. T. and W. A. Underhill. The varieties set were Catawba and Isabella; the vineyard was subsequently enlarged to cover about seventy-five acres and for some time practically supplied the market of this district. In 1829, Rufus Barrett of New Paltz, who probably received his inspiration from a colony of French Huguenots with whom he lived, began shipping Isabella grapes

to New York. Two years later John Jacques, a Frenchman, secured vines of Isabella and Catawba from Prince of Long Island, and planted a vineyard at Washingtonville, Orange County, some vines of which still live and are probably the oldest vines in New York. In Ulster County near Clintonville, William T. Cornell set a vineyard to Isabella in 1845. The Census Report for 1890 places the vineyards of this District at 13,000 acres; the reports ten years later showed a decrease of nearly one-half; an estimate in 1906–7 by this Station, places the present acreage by counties as follows: Columbia, 865; Dutchess, 488; Orange, 865; Ulster, 4,021; making a total of 6,199. This decrease is largely due to the discarding of a number of old vineyards, planted with worthless varieties, or too many of them, and the giving up of plantations poorly set or located. Indications now point to a prosperous condition for the district. Of the varieties grown in this region Concord leads followed by Delaware, Niagara, Worden, Moore Early, Bacchus, Pocklington, Campbell Early, Hartford, Vergennes and a large number of minor varieties.

The Hudson River district may well be called the birthplace of American viticulture; here is to be found the oldest winery, the oldest vineyard, the first distributing point, the greatest number of varieties; and lastly there has been centered in this region a corps of viticulturists, whose memories will long be perpetuated by horticulturists.

The soils of this district are clay or gravelly loams with more or less coarse fragments of slate or shale. They have been formed from limestones, schists, shales and slates, of the geologic formation known as the Taconic Province. This province is a broad valley taking in Orange, parts of Ulster, Dutchess and Columbia counties in New York and extending westward across northern New Jersey into Pennsylvania. The land is more or less hilly and rolling, with some broad undulating plains.

In the southern Hudson Valley where grapes are grown, there is a wide range of temperature, and a comparatively

light rainfall during the growing season with the maximum in July. The temperature in the grape district is high in the summer owing to the southern winds and physical features of the country, and low in winter. The high summer temperature and relatively light rainfall in the growing season are very favorable to grape growing.

In the early attempts of grape growing in the Hudson Valley the European methods of training were often used. Experience with native varieties soon showed that vines should be trained so that a larger surface should be exposed to sunshine. Different methods of pruning in the District soon arose but the one which soon came into general use originated in Ulster County with William Kniffin and still bears his name. This method of training is sometimes called the drooping system as contrasted with the upright systems of the two former districts. The trunk extends to the top wire; the canes are tied horizontally to both wires on either side of the trunk, and the bearing shoots allowed to droop downward. The growers believe this system to be well adapted to the strong-growing varieties.

There is little uniformity in the packages used in this district owing to the diversity in nearby market demands. It is surpassed by none in its shipping facilities and markets. The fungus diseases are more destructive than the insect pests; black-rot being especially troublesome in some sections. Spraying has not been generally practiced, and the decrease in acreage during the past decade has been increased by fungus diseases.

THE NIAGARA DISTRICT.

The Niagara district is the smallest and of the most recent development of any of the grape districts of New York. It borders the Niagara River in Erie and Niagara counties, and the southern shore of Lake Ontario in Niagara, Orleans, Monroe and Wayne counties.

Up to 1886 when the Niagara grape was introduced into this district, there were but few vineyards along the Ontario Shore. During the few years following, heavy plantings of this variety

were generally made and it soon became evident that the region was well adapted to grape-growing, except in minor unfavorable localities which were soon abandoned for this purpose. In 1906–7 the acreage in this district was approximately distributed as follows: Erie County, 2,100; Niagara, 1,250; Orleans, 375; Monroe, 700; Wayne, 380; making a total of 4,800 acres.

Conditions in the southern part of this district, in Erie County, are similar to those described in the Chautauqua belt. The grape lands along the Ontario Shore are upon the Ontario Plain, which extends from the Niagara River, along the southern shore of the lake for nearly its entire length. The plain varies from four to nine miles wide and like the Chautauqua belt is bounded on the southern side by a high escarpment or "the mountain," though its influence is less marked. The surface of the plain is more or less rolling in its general character.

The prevailing soils are sandy, gravelly or clay loams, though in some parts stony and shaly. As far as they have been classified, they belong to the Dunkirk series.

Climatic conditions here are similar to those in the Chautauqua belt. As compared with inland sections, the summer temperature is more even and the winters less severe; the rainfall and dews are lighter; the fall frosts much later and the growing season longer. The winter months are characterized by much cloudy weather.

Concord and Niagara are grown chiefly; and, in the main, are marketed in Buffalo, Niagara Falls, Rochester and other nearby towns, or shipped to eastern markets. Black-rot is very destructive in the Niagara vineyards owing to the susceptibility of the variety.

SPECIES OF GRAPES.

An inspection of the parentage of the 161 varieties mentioned in the table beginning on page 508, will show that there are seven species represented. Of these, all are crosses or hybrids, except twenty-five; twenty-four of which are pure Labrusca. In sixty varieties the two species, Labrusca and Vinifera are

represented; in twelve, Riparia and Labrusca; in eight, three species, Riparia, Labrusca and Vinifera; while in one Manito, there are five. Further analysis shows the relative importance of each species in breeding and the extent to which it has been used as a parent. Out of the 161 varieties, Labrusca blood is found in 156, Vinifera in 104, Riparia in 27, Bourquiniana in 25, Aestivalis in 15, Lincecumii in 10, Rupestris in 5. While in a number of varieties the immediate parents are unknown and identification is made possible only by the "ear marks" shown by vine and fruit characters of the different species, in others the parentage has been carefully and accurately recorded by the breeder. In either case the significance of species in crosses and hybrids, with their characteristics, and incident strength or weakness, is worthy of brief mention.

Vitis aestivalis. The natural habitat of Aestivalis is from New York and New Hampshire south to Florida and westward to Kansas and Texas. It is vigorous in growth, with slightly pubescent, medium to rather thick canes, with heavy bloom; tendrils intermittent; leaves usually small, entire, three and five-lobed, bluish underneath; berries are small to medium, blue or black, tart and spicy, rich in coloring matter. Aestivalis is primarily a southern species, hardy, resistant to insects and fungi, endures drought well, and in the wild is adaptable to a wide range of conditions. It has been little used in breeding, ripens late, and has little promise horticulturally for the North.

Vitis bourquiniana.—Bourquiniana is supposed to be of hybrid origin; its natural habitat and consequently its wild form have not yet been found. It differs from Aestivalis in having thinner leaves, slightly reddish-brown shoots and under side of leaves, larger and sweeter berries and more deeply lobed leaves. Bourquiniana is represented by a number of southern varieties, Delaware being the only important northern variety supposed to have a portion of its blood. It promises to be of more value for the south than the north.

Vitis labrusca.— This species is indigenous to the Atlantic coast plain from Maine to Georgia. Wild vines have also been

found in the Ohio River basin. The vines are moderately vigorous in growth, shoots climbing, densely pubescent, with thick diaphragms and continuous tendrils; leaves large, thick, entire or three-lobed, very woolly on under side; clusters small, compact; berries medium to large, blue, red or white in color, shatter badly, with a very foxy odor. From this species came most of our cultivated varieties—156 out of 161 varieties mentioned in this bulletin have Labrusca blood in them. Labrusca is adaptable to a wide range of conditions under cultivation, is hardy, productive, and resistant to diseases; it is of first importance horticulturally in America east of the Rocky Mountains. The grape breeder has used it, with promising results, in crosses with other species. "Ear marks" of this species are continuous tendril, thick diaphragm, heavy pubescence, thick leathery leaves, foxy odor of fruit, shattering of the berries and large number of clusters per shoot.

Vitis lincecumii.— The home of this species is eastern Texas, western Louisiana, Oklahoma, Arkanas and southern Missouri. Growth vigorous, climbing or growing in clumps; shoots covered with rusty wool, tendrils intermittent; leaves very large, entire, three, five or rarely seven lobed, with rusty pubescence below; fruit ranges from small to large, typically black with heavy bloom. Being a southern species it requires a longer season to mature than that of New York, but its vine and fruit characters make it of interest to the southern breeder.

Vitis riparia.— The natural range of Riparia far exceeds that of any other of our native species; it is found from New Brunswick and Quebec southward to the Gulf of Mexico and west to the Great Salt Lake in Utah. Over this wide area it is found mostly in the river valleys and upland ravines. Vine vigorous to very vigorous, climbing; shoots smooth, slender; tendrils intermittent, diaphragm thin; leaves medium to large, thin, entire, shallowly three to five lobed, usually glabrous above, hairy or lightly pubescent below; cluster medium to small, compact; berries small to medium, black, with blue

bloom. The strong vine characters of Riparia have brought it into extensive use as a stock, but on account of the poor fruit there is not a single variety of the species of more than local importance. The breeder has used it sparingly in crosses and hybrids and it is found in only 27 of the varieties listed here. The species is characterized by thin, smooth leaves, intermittent tendrils, thin diaphragm, slender vigorous growth.

Vitis rupestris. Rupestris is a southern species, indigenous to southwestern Texas, eastern New Mexico, northward and south from southern Missouri, Indiana, Tennessee, Pennsylvania and the District of Columbia. The vine is typically a small, strongly branched upright shrub, rarely climbing; diaphragm thin, tendrils few, weak, usually deciduous; leaves small, glossy, folded, entire, glabrous on both sides; berries small, black or purple. It is hardy, drouth resistant, the roots growing deep into the soil instead of laterally, foliage not subject to rot or mildew. Of interest to the breeder as a hardy parent, though it has been used but little. The habit of growth and characteristic leaf render it easily detected in hybrids.

Vitis vinifera.—The original home of *Vitis vinifera* is probably somewhere in western Asia. Botanists have never agreed as to whether it is an elementary species or a combination of two or more, the original forms of which are obsolete. The vigor of the vine is variable in our climate, not so high climbing as some American species; tendrils intermittent; leaves rather thin, three, five or seven-lobed, usually glabrous, in some varieties hairy or downy when young; berries oval, very persistent to pedicel, flesh and skin adhering; very variable species in vigor, hardiness and shape and color of fruit. As mentioned previously *Vitis vinifera* has been very freely used by the American grape breeder in making hybrids with native species; 104 of the varieties mentioned have Vinifera blood to a greater or less extent. Unfortunately in all cases where there is Vinifera blood there is a correlated weakness in vine. Hardiness and resistance to disease are sacrificed in increasing the quality of the fruit.

It will be seen that there is a marked difference in the habitat, manner of growth, horticultural value and botanical characters of the different species. Descriptions in the table will show, in the variety, fruit and vine characters of the species. For example, we associate oval or oblong fruit, high quality, and weakness of vine with Vinifera; continuous tendrils, thick diaphragms and foxy fruit with Labrusca and thin diaphragm with Riparia. A careful analysis of varieties, from the standpoint of the species, will avoid many plantings of varieties, unsuitable on account of lateness, lack of hardiness, or undesirable fruit characters, on the part of the grower, and the production and dissemination of many worthless crosses by the breeder.

CATALOGUE OF GRAPES.

ABBREVIATIONS AND MARKINGS.

Berry. Size.— l, large; m, medium; s. small; v, very. Form.— r, round; o, oval; ob, oblong; ov, ovate.

Color.— a, amber; b, black; bl, blue; br, brown; g, green; p, purplish; r, red; w, white; y, yellow; dk, dark; l, light.

Cluster. Size.— l, large; m, medium; s, small; v, very. Compactness.— c, compact; m, medium; l, loose; v, very.

Horticultural status.— **, well recommended; *, recommended; +, worthy of trial; —, undesirable.

Fertility of flower.— f, self fertile; s, self sterile; pf, semi-fertile; ps, semi-sterile; —, after f or s indicates nearly fertile or nearly sterile.

Flavor.— a, acid; ar, aromatic; f, foxy; j, juicy; m, mild; r, refreshing; s, sweet; sp, spicy; spr, sprightly; t, tart; v, vinous.

Origin.— Place, abbreviations of states and counties; unk, unknown; date, dates indicate time of origin if known; otherwise date of first reference or time of introduction.

Quality.— b, best; vg, very good; g, good; f, fair; m, medium; p, poor; v, very.

Season.— e, early; m, mid-season; l, late.

Species.— Aest, *Vitis aestivails;* Bourq, *Vitis bourquiniana;* Lab, *Vitis labrusca;* Lin, *Vitis lincecumii;* Rip, *Vitis riparia;* Rup, *Vitis rupestris;* Vin, *Vitis vinifera.*

Stamens.— r, reflexed; u, upright.

Tendrils.— c, continuous; i, intermittent; ir, irregular (continuous and intermittent).

Use.— d, dessert; m, market; w, wine.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster Size	Cluster Compactness
1	Adirondack.....	Lab. Vin.?......	N. Y., 1861	c	pf	u	m +—s	c
2	Advance.......	Rip. Lab. Vin...	N. Y., 1870	i	—	u	m +	m
3	Agawam.......	Lab. Vin........	Mass., 1851	i—c	f	u	m—l	m—
4	Alexander......	Lab. Vin.?......	1804, —	—	—	—	—	c
5	Alexander Winter.....	Lab. Vin.?......	Ohio, 1884	i	s	r	m +—s	l
6	Alice...........	Lab. Aest.? Vin.	? N. Y., 1884	i	f	u	m	m—c
7	Allens Hybrid ..	Lab. Vin........	Mass., 1843	—	—	—	m—l	c
8	Amber Queen...	Vin. Rip. Lab...	Mass., 1870	i—c	s	r	m	l—m
9	Ambrosia.......	Lab. Vin........	N. Y., 1884	c	f	u	l—m	c—m
10	America........	Lin. Rup........	Tex., 1892	i	s	r	ab m	c
11	Amethyst......	Lab. Vin. Bourq.	Tex., 1898	c	f—	u	m—l	c
12	Aminia.........	Lab. Vin........	Mass., 1851	i	s	r	m—s	l
13	Antoinette......	Lab............	N. J., 1872	c	f	u	m—s	m
14	August Giant...	Lab. Vin........	Mass., 1861	c	s	r	m	m
15	Autuchon......	Rip. Lab. Vin...	Can., 1859	—	—	—	l	l
16	Bacchus........	Rip. Lab........	N. Y., 1879	c	s	u	s—m	c
17	Bailey.........	Lin. Lab. Vin....	Tex., 1877	i	f	u	l	c
18	Banner.........	Lab. Vin. Bourq.	Ark., 1898	—	—	—	l	vc
19	Barry..........	Lab. Vin........	Mass., 1851	i	s	r	m—l	c
20	Beacon.........	Lin. Lab........	Tex., 1887	i	f—	—	l	c—m
21	Beauty.........	Lab. Vin. Bourq.	Mo., 1877?	c	f?	—	m	c—m
22	Bell...........	Rip. Lab. Bourq. Vin..........	Tex., 1881	i	f—	u	m	c—m
23	Berckmans.....	Rip. Lab. Bourq.	S. C., 1868	i	f	u	m—s	c

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
1	m	r	pb	s	g—vg	e	d	—	Slow grower; injured by severe weather. Nearly obsolete.
2	m—l	o	p b	sp	g	m	—	—	Not hardy, subject to mildew. Nearly obsolete.
3	l	r—o	p r	f	g	m	dwm	*	*Rogers No.* 15. Keeps well. Later than Concord.
4	m	o	b	m	—	l	w	—	Of historical interest; not grown now.
5	m—l	r	r	v	g—vg	—	d	—	A good keeper; sets fruit imperfectly; ripens unevenly.
6	m—s	r	r	v f	g	m	d	—	Of little value in New York.
7	m—l	r	w—y w	s v	g	e	d	—	The first named hybrid to be disseminated. Obsolete.
8	m	r—o	dk r	f	g—vg	m	d	—	Undesirable except in favored localities.
9	l—m +	sl ob	g—yg	s	m—vg	m	d	—	Has not found favor with grape growers.
10	m—s	r	b	s v	g	m	w	+	Keeps well. May have value as a wine grape.
11	ab m—s	r—o	dk r	v s	g—vg	m	d w	+	Worthy of trial for home use.
12	m	r	b	f s	g	e	d	—	Surpassed by other early grapes for home use.
13	l—m	r	g—gy	sl f	g—vg	m	d	—	Excelled by other white grapes of its season.
14	l	o—r	pr—b	t	g	m	d	—	Desirable as an ornamental vine. Quality high.
15	m	r	g	spr	—	m	w	—	Not resistant to cold and diseases; an unreliable bearer.
16	m—s	r	b	vs	m	l	w	*	A desirable grape for dark red wine. Hardy and productive.
17	m—l	r	pb—b	v	g	l	d	—	Too late for New York except in favorable seasons.
18	m	r	ar	s	g—vg	m—l	dm	+	Worthy of trial.
19	l	o—r	pb—b	vs	above m	m	dm	*	Keeps well. Recommended for home use.
20	m	r	pb—p	v sp	g	m	d	—	Ripens with Concord. Not adapted to New York.
21	m	r	pb—b	sp v	g	m—l	dw	—	Practically lost to cultivation.
22	m—s	r	g—yg	s	f	m	—	—	Not recommended for New York.
23	m	r—o	dk r	vs	g	m	d	+	Fruit and vine characters very good in some soils.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster Size	Cluster Compactness
24	Black Eagle....	Lab. Vin........	N. Y., 1866	c	s	r	l—m	l—c
25	Black Pearl.....	Rip. Lab........	Ohio, 1877?	—	s	r	s—m	m—c
26	Brighton.......	Lab. Vin........	N. Y., 1870	c	s	r	vl—m	m—l
27	Brilliant........	Lab. Vin. Bourq.	Tex., 1883	i	f	u	m	m—c
28	Brown.........	Lab. Vin........	N. Y., 1884	c	f—	u	m—s	l—m
29	Campbell Early.	Lab. Vin........	Ohio, 1892	i	f	u	vl—m	c—m
30	Canada........	Rip. Lab. Vin...	Can., 1860		s—	u	m	vc
31	Canandaigua ...	Lab. Vin........	N. Y., 1897?	ir	s—	r	l—s	l—m
32	Captain........	Lin. Rup. Lab. Vin..........	Tex., 1901	i	p f	u	l	l
33	Carman........	Lin. Vin. Lab. Bourq........	Tex., 1892	i	f	u	av m	c
34	Catawba.......	Lab. Vin........	N. C., 1823	i—ir	f	u	l—m	m—c
35	Cayuga........	Lab. Vin.?......	N. Y., 1886	c	p s	u	m	m
36	Centennial......	Lab. Aest. Vin...	N. Y., 1875	—	—	—	m—s	c
37	Champion......	Lab............	Am., 1870	c	f	u	m—s	m—c
38	Chautauqua....	Lab............	N. Y., 1892	c	—f	u	m—l	m
39	Clevener.......	Lab. Rip. Aest..	unk., 1867?	c	s	r	s—m	m
40	Clinton.........	Rip. Lab........	N. Y., 1823	ir	f	u	m—s	c
41	Cloeta.........	Lin. Rup. Lab. Vin..........	Tex., 1902	i	f?	u	m—s	m
42	Colerain........	Lab............	Ohio, 1880	c	f	u	m	m
43	Columbian Imperial.........	Lab. Rip........	Ohio, 1885	c	f	u	m	m
44	Concord........	Lab............	Mass., 1843	c—ir	f	u	l—m	c

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
24	l	o	b	v s t	g	m	d	+	Not a commercial variety.
25	bl m—vs	r—o	b	sp t	m	l	w	+	Resembles Clinton and makes good red wine. But little known in New York.
26	m—l	r—o	r	vs	vg	m	dm	**	High quality, productive; earlier than Concord; a good market grape.
27	m—l	r—o	dk r	vs	g—vg	m	dm	*	Ships and keeps well; grown somewhat for market.
28	m	r—o	b	f m	g	e	d	—	Once thought to be promising, but has proved inferior to other varieties.
29	l	r	pb	sl v	g	e	dm	**	One of the standard commercial grapes of New York.
30	m—s	r	pb—b	sp v	m—f	m	w	*	Well known in New York as a wine grape.
31	l—m	o—r	b	s	g	m—l	d	+	One of the best keepers. Worthy of growing for home use.
32	l—m	r	b	t	f	m	—	—	Of little value in New York.
33	s—m	r—ob	pb—b	v sp	g—vg	l	d	—	Long keeper, but too late for New York.
34	m	o—r	pr	vs	vg	l	dwm	**	One of the four leading commercial varieties in New York.
35	m—l	rp—b	rp—b	vm	f—g	e	d	—	Not a commercial variety.
36	m—s	—	r—a	s	g—vg	m	d	—	Excelled by better varieties; lacks vigor and hardiness.
37	m—ab m	r	b	f s t	p	e	m	*	An early market grape, ships well, is hardy but poor quality.
38	l	r—o	pb	vs	g—vg	e	d	—	Surpassed by Concord.
39	s—m	r—ob	b	s	m	l	w	—	Makes a good dark red wine.
40	s—m	r	pb—b	s v t	m	l	w	—	A variety of historical interest but little grown now, being surpassed by better wine grapes.
41	m—s	o—r	b	s sp	m—f	l	d	—	Not suited to New York.
42	m	r—o	g	f v s	g	e	d	+	A good early white grape for home use.
43	l	r—o	rb	a s	f—g	l	—	—	Of little value; of interest on account of large size.
44	ab m—l	r	b	s sl f	g	m	dm	**	Hardy and productive. The standard market grape in New York.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster	
							Size	Compactness
45	Cottage........	Lab............	Mass., 1868	c	f	u	ab m—s	c
46	Creveling.......	Lab. Vin........	Pa.,? 1857	c	s	r	m	l
47	Croton.........	Vin. Lab. Bourq.	N. Y., 1863	i	f	u	vl—m	l—m
48	Cynthiana......	Aest. Lab.......	Ark., 1863	ir	f?	u	m—s	c
49	Daisy..........	Lab. Vin........	Kan., 1886	c	s	u	m	l
50	Delaware.......	Lab. Bourq. Vin.	N. J., 1849?	i	f	u	m—s	c
51	Delawba.......	Lab. Vin. Bourq.	Tenn., 1880	—	f	—	m—l	m
52	Diamond.......	Lab. Vin........	N. Y., 1870	i	f	u	m—l	c
53	Diana..........	Lab. Vin. Aest...	Mass., 1834	i	f	u	m—l	c—m
54	Downing.......	Vin. Aest. Lab...	N. Y., 1865	i	f?	u	l	l—c
55	Dracut Amber..	Lab............	Mass., 1855	c	f—	u	m	c—m
56	Dutchess.......	Vin.? Lab. Bourq.? Aest.?	N. Y., 1868	i	f	u	l—m	m—c
57	Early Daisy....	Lab............	Pa., 1874	c	s	—	s—m	c
58	Early Dawn....	Lab. Vin. Aest...	N. Y., 1870	i	s	sr	m—l	m
59	Early Ohio.....	Lab............	Ohio, 1882	c	f	u	m	m
60	Early Victor....	Lap. Bourq....	Kan., 1871	c	f—	u	m—s	c
61	Eaton..........	Lab............	N. H., 1868	c	pf	u	l—m	c—m
62	Eclipse.........	Lab............	Ill., 1890	c	s	r	m	m

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
45	m	r	b	f s	g—m	e	dm	*	Ships and keeps well. A desirable early grape of Concord type for home use or market.
46	m—l	o	b	f s	g	e	d	+	A light bearer; not grown commercially but is found in varietal vineyards.
47	m	r—o	g—yg	v s	g—vg	m	d	*	Difficult to grow, tender. In suitable localities surpassed by none of the green grapes for home use.
48	s	r	b	s t	p	l	w	—	One of the best for red wine. Cannot be grown in New York.
49	m—s	o	r	v s	g	m	d	—	Not worth perpetuating.
50	s—m	r	l r	v sp s	b	m	dm w	**	The standard American grape of quality. Used extensively for home use, market and wine.
51	av m	—	a	—	g—vg	m	d	+	Worthy of trial because of high quality.
52	ab m—m	r—ov	g—yg	sp	vg	m	dm w	**	One of the best white grapes. Worthy of more general cultivation.
53	m	r—ov	l r	v f s	g	m	md	+	Not hardy. A good grape for home use.
54	l—m	o	p b	v m	vg	m	d	+	Keeps well, high in quality. A good grape for home use. Not hardy.
55	m—l	o—r	dk a	vf	p—m	m e	d	—	Hardy; poor in quality.
56	m	r—o	yg—a	vs	vg—b	m	d	*	Subject to fungi; not hardy. Excelled by few for home use.
57	m	r	b	t	p	e	d	+	Though not in favor with grape growers, its earliness should recommend it.
58	s	r	p b	v t	f—g	e	d	—	Weak in vine characters.
59	m	r	p b	s a	p	e	d	—	Grown to some extent but going out of favor.
60	s—m	r—ob	dk pb	ar v s	g	e	d	+	High in quality for an early grape; is but little grown and deserves a better place in viticulture.
61	l—vl	r	b	f	f	d	m	+	A large seedling of Concord.
62	l—m	sl ov	b	f s t	g	m e	d	+	A new grape, being a seedling of Niagara. Worthy of trial.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster Size	Cluster Compactness
63	Eldorado	Lab. Vin.	N. Y., 1870	i	s	r	av m	—
64	Elsinburgh	Vin. Aest.	N. Y., 1827?	i	—f	u	m—l	l—m
65	Elvicand	Can. Rip. Lab.	Tex., 1892	—	f	u	s	l
66	Elvira	Rip. Lab.	Mo., 1863	c	f	u	m	c
67	Empire State	Rip. Lab. Vin.?	N. Y., 1879	i	f	u	l—m	m—c
68	Essex	Lab. Vin.	Mass., 1852	ir	s	r	m—l	c
69	Etta	Rip. Lab.	Mo., 1879	c	f	u	m—s	vc
70	Eumelan	Lab. Vin. Aest.	N. Y., 1847	i	s	r	m	c—m
71	Eureka	Bourq. Lab. Vin.	Kan., 1880	—	—	—	ab m—m	m
72	Excelsior	Vin. Lab.	N. Y., 1880	i	—	—	l	l
73	Faith	Rip. Lab.	Mo., 1881	c	s	u	m—s	l
74	Fern Munson	Lin. Vin. Lab.	Tex., 1885	i	pf	u	m—l	m—l
75	Gaertner	Vin. Lab.	Mass., 1852	c	s	r	ab m—m	l
76	Geneva	Vin. Lab.	N. Y., 1874	ir	pf	u	m—ab m	m
77	Glenfeld	Lab.	N. Y., 1889	ir	f—	u	l—m	l—c
78	Goethe	Vin. Lab.	Mass., 1852	c	pf	u	m	m
79	Goff	Lab. Vin. Aest.	N. Y., 1885	c	f	u	l—m	c
80	Gold Coin	Aest. Lab.	Tex., 1883	c	f—	u	m—s	m
81	Grein Golden	Rip. Lab.	Mo., 1877?	i	s—	r	l	l—m
82	Hartford	Lab. Vin.	Conn., 1849	c	f	u	ab m	l
83	Hayes	Lab. Vin.	Mass., 1872	i	s	u	m	m
84	Headlight	Vin. Lab. Bourq.	Tex., 1895	c	s	s	s	c
85	Herbemont	Bourq.	South, 1825?	i	f		l	c

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
63	l—m	r	yg—y	f s m	g—vg	e	d	+	A high flavored early grape, of little commercial value but of some interest to amateurs.
64	s	r	b	vs	g	m	w	—	An old variety now rarely cultivated.
65	m	r	b	suba	f g	l	—	—	Of little value.
66	m	r—ob	g—gy	f s	f	m	w	+	Grown for a light wine.
67	m	r	yg	s	g—vg	m	d w	**	One of the standard green grapes of high quality.
68	l—m	r—o	pb	vs	g—vg	m	d	—	Not hardy; self-sterile. Surpassed by better black grape of its class.
69	m—s	r	g—yg	f s	m	l	w	—	Too late for New York.
70	m	r	b	sp ar	g	e m	d w	+	Its good qualities should recommend it.
71	m	r	dk r	ar av	g	m	d	—	A seedling of Delaware and surpassed by it in nearly all desirable characters.
72	l—m	o—r	dk r	s spr	g—b	l	d	+	A good grape but too late for New York. Of interest to amateurs.
73	s	r	g—yg	st	f g	m e	d?	—	Of little value for New York.
74	m—l	r—ob	pb	vsuba	g	l	d	—	Not hardy in New York.
75	l—m	r—o	dk r	v s t	g—vg	m	d	+	Deserving better recognition.
76	m—l	o—ob	g—gy	v s t	f—g	m	d	—	Surpassed by other grapes of its season.
77	l—m	r	olive g	st	g	m	d	—	Excelled by others of its season.
78	vl—ab m	o—r	r	st spr	g—vg	l	d w	—	Very vigorous, hardy; ripening too late for most seasons in New York.
79	l—m	ob	dk rp	v s v	vg	m	d	+	A new grape of high quality; an excellent keeper.
80	l—m	r—o	y g	ar t	g	l	d w	—	Too late for New York.
81	l	r	lg—gy	va	m—g	m	w	—	Does not reach its best quality in New York.
82	ab m	r—o	b	f s	m	e	d	—	Superseded by better early grapes of its season.
83	m—s	r	gy	v s t	g	e	d	—	Better grapes of its season in New York.
84	m—vs	r	dk r	vs	g—vg	m	d	+	Worthy of trial in both commercial and amateur vineyards.
84	below m	r	r b	spr	g—vg	v l	d w	—	An old Southern variety. Not desirable for Northern climate.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster Size	Cluster Compactness
86	Herbert........	Lab. Vin........	Mass., 1852	i	s	r	m—l	l
87	Hercules.......	Lab. Vin........	Ill., 1892	c	s	r	vl m	m—c
88	Hicks..........	Lab............	Cal.,? 1898	c	f	u	l—m	m
89	Hidalgo........	Vin. Lab. Bourq.	Tex., 1902	ir	f—	u	l	m—c
90	Highland.......	Vin. Lab........	N. Y., 1865	i	f	u	l	m
91	Hosford........	Lab............	Mich., 1876	c	pf	u	m—l	m
92	Hybrid Franc...	Vin. Rup.......	France 1903?	i	pf	u	m	m—c
93	Ideal..........	Lab. Vin. Bourq.?......	Kan., 1886	i	—	—	l—m	m
94	Iona...........	Lab. Vin........	N. Y., 1855	i	f—	u	av m	m—l
95	Ironclad........	Rip. Lab........	Unk., 1873?	c	s?	r	s	m
96	Isabella........	Lab. Vin........	S. C., 1816	c	f	u	l—m	a v m
97	Isabella Seedling	Lab. Vin........	Ill., 1889	ir	f—	u	l—m	l—m
98	Israella........	Lab. Vin........	N. Y., 1855	c	f?	u	ab m	c
99	Ives...........	Lab. Aest.......	Ohio, 1840	c	f?	u	m	c—m
100	Jaeger.........	Lin. Bourq......	Tex., 1885	i	f?	u	m—l	vc
101	Janesville......	Lab. Rip........	Wis., 1858	ir	f	u	m—s	c
102	Jefferson.......	Lab. Vin........	N. Y., 1874	i	f	u	l—m	m—c
103	Jessica.........	Lab. Vin........	Can., 1870?	ir	f—	u	m—s	m

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
86	ab m	rs	b	t	g—vg	m	d	*	On account of quality, one of the best table grapes.
87	l—vl	r	b	f	f—g	m	d?	—	Of little value commercially.
88	l	r	pb—b	f s m	g	m	d m	+	Very similar to Concord and a little earlier. Promising.
89	ab m	o	gy	ar s	vg—b	m	d	+	May prove of value in favorable locations. A new grape of high quality.
90	l	ro	pb—blb	v	g	l	d	+	Though grown for some time it is not widely distributed owing to lateness in ripening.
91	l—m	r—o	b	vs	g	m	d	—	Of doubtful value when compared with others of its season.
92	m—s	ob—r	b	sp t	f	m	w	—	Of French origin. Hardy, vigorous and productive.
93	l	r	dk r	ar	g—vg	m	d	—	May be of value for home use.
94	m	o	r	v	vg	m	dw	*	Demands careful culture; subject to fungus disease, yet is standard in quality. Suitable for home use.
95	s	r	b	sp t	m	m	w	—	Probably one of our oldest varieties. Not a table grape.
96	m	o	b	f s	g	m l	d w	—	Nearly obsolete.
97	l—m	o	b	m s v	g	e	d	+	Grown commercially in New York to some extent, but not an important variety.
98	s—m	r—o	b—pb	m	f	m	d	—	Gradually being dropped from cultivation.
99	m	o—r	b	f s t	f	m	m w	*	An old variety still grown for red wine.
100	m—s	r	b	sp t	g	m	d w	—	A southern grape not maturing well in the North.
101	m	o	b	tart	f	m e	d w	*	On account of hardiness it has place in regions of severe climates where better varieties cannot be grown.
102	m	o—r	dk r	s v t	g—b	l	d m	+	Lacks hardiness, requires a long season, temperate climate, and careful culture. Few red grapes better.
103	s—m	r	l g	spr s	g—ab g	e	d	+	Recommended in northern regions for its earliness and hardiness.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster	
							Size	Com-pactness
104	Jewel..........	Lab. Bourq. Vin.	Kan., 1874	c	s	r	m—s	m—c
105	Kensington.....	Vin. Rip. Lab...	Ont., 1870	ir	f	u	m—l	l—m
106	Lady..........	Lab. Vin........	Ohio, 1874	i	f	u	av m	c
107	Lady Washington..........	Lab. Vin........	N. Y., 1877	c	f	u	l—m	l—m
108	Lindley........	Lab. Vin........	Mass., 1852	c	s	r	m	m
109	Lucile..........	Lab............	N. Y., 1888	c	f	u	m—l	vc
110	Lutie..........	Lab............	Tenn., 1884	c	f	u	m—s	c
111	McPike........	Lab............	Ill.,...1890	c	f	—	l	m
112	Manito.......	Lab. Vin. Bourq...... Lin. Rup......	Tex., 1895	c	pf	u	l—m	l
113	Marion.........	Rip. Lab........	Pa.,? 1858	c	s	r	m	c
114	Martha.........	Lab. Vin.?......	Pa., 1868	ir	f	u	m	m
115	Massasoit.......	Lab. Vin.........	Mass., 1852	c	s	r	av m	m
116	Maxatawney....	Lab. Vin........	Pa., 1844	c	s—	u	s—m	m
117	Merrimac.......	Lab. Vin........	Mass., 1852	i	s	r	m	m
118	Mills............	Lab. Vin........	Ont., 1870	i	f—	u	l—m	c
119	Missouri Riesling..........	Rip. Lab........	Mo., 1870	c	p f	u	av m	m—c
120	Monroe........	Lab. Bourq?.....	N. Y., 1867	c	f	u	m	m—c
121	Montefiore......	Rip. Lab........	Mo., 1879	c	s	u	m—s	c
122	Moore Early....	Lab............	Mass., 1871	c	f	u	m	m

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
104	m	r—o	p b	spr v	g—vg	e	d	+	One of the best early grapes for severe climates.
105	av m	o	g—yg	vs	g	m	d	*	Its hardiness and high qualities should recommend it for northern gardens.
106	l—m	r	g—gy	ar s	vg	e	d	*	A Concord seedling of high quality. A good amateur grape suitable for local markets.
107	l—m	r—ob	dkg—ya	ar s	g—vg	m	d	+	Desirable for home use.
108	l—m	r	dk r	v st	g—b	m	d m	*	A favorite for the garden; good appearance; ships well.
109	l—m	r—o	dk r	v f	f—g	e m	d m	*	A hardy, vigorous red grape, suitable for short seasons and severe weather. Quality poor.
110	l—m	r	dk r	v f	f—g	e m	d	*	Worth growing only where better varieties cannot be grown. Hardy.
111	l—vl	r	pb—b	v s j	f—g	m	d	+	Its lack of productiveness and tender skin debar it from becoming a commercial grape.
112	m	r	p b	s t	g	e	dw	+	Does not reach its best quality in New York.
113	m—s	r	b	sp	f	m	w	+	An old variety grown in some localities for wine.
114	m	r	g—yg	f m	g—vg	m	dw	—	Other varieties better for the North. Does not ship or keep well.
115	l—m	r	dk br r	f	g—vg	m	d m	+	Vigorous and hardy but subject to mildew and rot. Recommended for home use.
116	m—l	o	g—ag	fs—t	g—vg	l	d	—	Not a northern grape; subject to fungus diseases; late in ripening.
117	l—m	r	b	j	g	m	d m	+	Ships and keeps well; good grape for home use.
118	l	o—r	dk r—b	t v s	vg—b	m—l	d m	+	Variable; mildews; not hardy. Not excelled in fruit characters. Keeps well.
119	m	r—o	yg—ry	s m	f	l	d w	—	Too late for northern climate.
120	m—ab m	r	b p b	m	f	e	d	—	Nearly obsolete.
121	m—s	m	b	j v s t	f—g	m	w	—	A red wine grape, not of commercial value.
122	l—ab m	r	pb—b	f s	f—g	e	d m	**	The standard early commercial grape of New York.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster Size	Cluster Compactness
123	Moyer.........	Lab. Bourq.....	Ont., 1880	c	s	r	m—s	m
124	Naomi.........	Vin. Rip. Lab...	N. Y., 1879	i	f?	u	l—m	c
125	Nectar.........	Lab. Bourq. Vin?	N. Y., 1880	i	pf	u	m	m—c
126	Niagara........	Lab. Vin........	N. Y., 1868	c	f	u	l—m	m
127	Noah..........	Rip. Lab........	Ill., 1869	c	p f	u	l—m	m—c
128	Norfolk........	Lab. Vin........	Mass., 1865?	i	f—	u	m—s	l—m
129	Northern Muscadine.......	Lab............	N. Y., 1852	c	p f	u	m—s	m—c
130	Norton.........	Aest. Lab.......	Va., 1830	i—ir	f	u	m	m—c
131	Norwood.......	Vin. Lab........	Mass., 1880	ir	s	r	l—m	m
132	Oneida.........	Vin. Lab........	N. Y., 1871	c	s	u	s—m	l
133	Oporto.........	Rip. Lab........	unk., 1860	c	s	r	m—s	c
134	Othello.........	Vin. Rip. Lab...	Ont., 1859	c	f?	u	vl—ab m	c
135	Ozark..........	Aest. Lab.......	Kan., 1889	i	s	r	m—l	vc
136	Perkins........	Lab. Vin........	Mass., 1830	c	f	u	m	c
137	Pocklington....	Lab............	N. Y., 1870	c	f	u	m—l	m—c
138	Poughkeepsie...	Bourq. Lab. Vin.	N. Y., 1860?	i	f	u	m	vc
139	Prentiss........	Lab. Vin........	N. Y., 1870	c	f	u	m—s	c
140	Rebecca........	Lab. Vin........	N. Y., 1848	c	f	u	m—s	c
141	Red Eagle......	Lab. Vin........	Tex., 1885?	ir	s	r	m—s	l—m
142	Regal..........	Lab. Vin........	Ill., 1879	i	f	u	s—m	vc
143	Requa.........	Lab. Vin........	Mass., 1851	ir	s—	r	l—m	c

Number	Berry Size	Berry Form	Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
123	m—s	ob	dk r	j v	g—vg	m	d m	*	Resembles Delaware, is hardier but below it in quality, vigor and productiveness.
124	m	r	lg	ar s	g	l	d	—	Too late in ripening. Nearly obsolete.
125	m	r	dk pb	j s a	g—vg	m	d	—	Susceptible to mildew. Other grapes better.
126	ab m—l	o	g—yg	f s t	g—vg	m	d m	**	The standard white grape for the commercial grower.
127	m—s	r	g—yg	vt spr	g	m	w	—	A wine grape of little commercial importance in New York.
128	l—m	o—r	dk pr	v s t	f	m	d	—	Weak in vine characters. Now scarcely cultivated.
129	m—l	r—o	dk r	v f s	p	m e	d w	—	A typical red Labrusca, very foxy; not recommended.
130	m—s	r	b	s t	p	l	w	—	A leading wine grape but too late in ripening for New York.
131	l	r—o	p b	—	g—vg	m	d	—	Sets fruit poorly. Not a grape for either the amateur or commercial grower.
132	av m	r	r	v spr	f—g	m	d	—	Of doubtful value.
133	m	r—ob	b	s sp	f	m	w	—	Grown some for wine but nearly obsolete.
134	l—m	o—r	b	spr	p	l	w	—	Late in ripening. Of little value for short growing seasons.
135	m—s	r	b	m	f	l	w	—	A southern wine grape. Too late in ripening for northern season.
136	l—m	o	g	f t	p—f	m	d	—	At one time grown as early grape, now being discarded.
137	l—m	ob	yg—a	j s t	g	m	d	*	Recommended for home use on account of quality. One of the best green grapes.
138	s	r	r	vs	vg—b	m	d	—	Nearly obsolete; never widely disseminated.
139	m—s	r—o	g—yg	s l	g	m	d	—	Poor in vine characters
140	m	o	g—yg	j v s	g—vg	m	d	—	Difficult to grow. Going out of cultivation.
141	av m	r	r	j f t	vg	m	d	+	High in quality. An amateur variety.
142	av m	r	pr—dkr	s t m	g	m	d m	+	Worthy of extensive trial for market and home use.
143	m—l	o—r	dk r	s v	g—vg	l	d	—	Attractive berry and bunch; late in ripening for New York; subject to rot.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster Size	Cluster Compact-ness
144	Rochester......	Lab. Vin.........	N. Y., 1867	i	f	u	l—m	vc
145	Rommel........	Lab. Rip. Vin....	Tex., 1885	i	p f	u	av m	c—m
146	R. U. Munson...	Lin. Lab. Vin....	Tex., 1887	i	s	u	m—l	c—m
147	St. Louis.......	Lab............	Mo., 1897	c	f	u	l—m	m—c
148	Salem..........	Lab. Vin........	Mass., 1851	c	s	r	m—l	c
149	Secretary.......	Vin. Rip. Lab...	N. Y., 1867	i	p f	u	m—l	m—l
150	Senasqua.......	Lab. Vin........	N. Y., 1863	i	f	u	l—m	vc
151	Taylor.........	Rip. Lab........	Ky., 1840	—	s?	r	s—m	l—m
152	Triumph.......	Lab. Vin........	Ohio, 1860	i	f	u	vl—m	c
153	Ulster..........	Lab. Vin........	N. Y., 1885	i	f	u	m	c
154	Vergennes......	Lab............	Vt., 1870?	c	s—	u	m	m
155	Walter..........	Vin. Lab. Bourq.	N.Y., 1850	i	f?	u	m	c
156	Wapanuka.....	Lab. Rip. Vin. Bourq........	Tex., 1898	c	f—	u	m	c
157	Wilder.........	Lab. Vin........	Mass., 1851	i	s	r	av m	l—m
158	Winchell.......	Lab. Vin. Aest...	Vt., 1850	ir	f	u	l—m	l—m

Number	Berry		Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
	Size	Form							
144	av m	o	dk r	v s	g—vg	e m	d	*	An early red grape, worth a place in the home vineyard.
145	l—m	o—r	g—yg	s	f—g	m	d	—	Rarely cultivated in New York.
146	m—l	ob	b	v s—t	g	m	d	+	Promising. Resistant to blackrot.
147	l—m	r	b	f s	g	m	d	+	Fruit resembles Concord. May prove of some value for New York as an early grape.
148	l—m	r	dk r	spr v	g—vg	m	d m	*	Grown but little; deserves better recognition for market and home use.
149	l—m	o	pb	vs	g	m	d	+	Very subject to rot and mildew. Can be grown only in favored localities.
150	ab m	r	rb—b	v sp spr	g	m	d	—	Weak in vine characters; recommended only for the garden.
151	s—m	r	g w	s sp	f—g	m l	w	—	Excelled by other varieties.
152	m—l	o	g—yg	v j	g—vg	l	d	+	One of the finest green dessert grapes. Unfortunately it ripens too late for most seasons in New York.
153	ab m—m	r o	dk r	j ar s	g—vg	m	d	—	Over-productiveness and lack of vigor debar it from the commercial class in New York.
154	l—m	o—r	r	v s l	g—vg	m	d m	*	Keeps and ships best of any of the Labrusca class. A good red grape for breeding, market or home use.
155	s—m	ov	r	ar v	g—vg	m	d m	+	Subject to mildew; difficult to grow. But few better red grapes. An amateur rather than a commercial sort.
156	l	r	y g	f s m	g	m	d m?	+	Worthy of trial in New York for market and home use.
157	l	sl o	b—pb	spr s	g	m	d	+	Should be planted more generally for special and local markets.
158	ab m—s	r	l g	j s	vg—b	e	d m	**	The standard early green grape for New York.

Number	Variety	Species	Origin	Tendrils	Sexual status	Stamens	Cluster	
							Size	Com-pactness
159	Woodruff.......	Lab. Vin........	Mich., 1874	c	p f	u	av m	c
160	Worden........	Lab............	N. Y., 1863	c	f	u	l	c
161	Wyoming......	Lab............	Pa., 1861?	c	s	r	m—s	c—m

Number	Berry		Color	Flavor	Quality	Season	Use	Horticultural status	Remarks
	Size	Form							
159	l—m	r—o	dk r	v f	f	m	d	—	Not worth growing where other red varieties of its class succeed. Fruit characters poor.
160	l	r	dk p—b	s j f m	g—vg	e m	d m	**	The standard early black grape in New York for home use and market.
161	ab m—s	r	dk r—a	v f	p	e m	d	*	Hardy, productive and early, but is low in quality.

ORCHARD MANAGEMENT.*

U. P. HEDRICK.

The management of an orchard is not a matter to be settled by one man for another. To do so is quite as impossible as it is to tell a man how to manage a business enterprise, a clergyman how to preach, a teacher to teach, or a lawyer to win cases. But some methods are common to all business, there are fundamentals in theology, teaching is based on pedagogy, and every lawyer must know something of Blackstone. So, too, there are generalities which apply to all fruit growing. The better a man can ground himself in these, the more successful he ought to be in growing fruit. The word "generalities" is used in preference to the more pretentious ones "principles" and "fundamentals;" these imply that fruit growing is a science, which it is not, but an art to which a number of sciences contribute. It is well to understand this at the outset and so not expect in discussing horticulture the principles and formulæ of an exact science.

Coming now to the subject. *Orchard management;* let us approach it by outlining the ground to be covered. The fruits of this climate fall into three classes, tree-fruits, vine-fruits, and small fruits. Orchards are plantations of any of these but we restrict the term in this discussion, as in common parlance, to plantations of tree-fruits. To classify still further, orchards are planted with two general objects in view, to produce fruits for home use and for the market. Again commercial fruit growing is divided into that for a special market and that for the general market. Necessary brevity forbids specific discussion of these three divisions of orcharding but the fruit grower must not lump them together in this rough-and-ready way. The ideals for each are distinct and the methods that succeed in one division may not succeed in another. The very first question for the fruit grower to settle is, as to whether he

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is to grow for home use, a special market or the general market. Upon this decision largely rests the choice of location and the choice and number of fruits and of their varieties.

Still another division may be made. A man may elect to grow fruit extensively or intensively. In the first case the orchard is the unit; in the second, the tree. Most of the orcharding in America is extensive. Everything is done on a large scale. There are many acres; few varieties; uniformity of method for all varieties; wholesale packing and handling; and satisfaction with a low price. In Europe the fruit growing is intensive. Orchards are small; there are many varieties; special conditions and treatment are given each variety; individual trees are carefully trained, pruned and fertilized; the product is packed with all of the niceties known to the trade and sells for a high price. America will long continue to grow fruit extensively and conditions are such that it is far best she should, but her fruit growers could learn much from the intensive methods of the European fruit grower; especially learn to look more carefully after the individual needs of trees; learn, too, " That large orcharding is sometimes small orcharding and small orcharding is often the largest orcharding."

Whatever the kind of fruit growing, the choice of place upon which to grow it demands exceedingly careful attention. All subsequent efforts will fail if a mistake is made in choosing the site for operations. Here, indeed, is " Well begun, half done." In growing fruit for the market certain economic considerations demand attention; as distance to market, means of transportation, labor, storage, competition, disposition of by-products, cost of production and over-production. Any of these may prove a determinant of success and each should receive careful consideration. " The weakest goes to the wall " applies in the business of growing fruit as well as in other business enterprises. In growing fruit for home use, these economic factors may be ignored. There are, however, certain natural factors which must be observed in fruit growing for both home and market.

The first of these is latitude which largely determines the annual temperature, the amount and intensity of sunlight, and the length of the growing season. Now a man must select his fruits and even more particularly his varieties with reference to latitude and its equivalent, altitude. It is easy enough to select the fruit or fruits for a region in a certain altitude or latitude but it is far from easy to select the varieties of a particular fruit. Thus the Ben Davis, Winesap, Romanite and York Imperial groups of apples belong in southern latitudes, while the Concord grape and its seventy or more named offspring belong to the North. So with nearly all varieties of our fruits; they are either Northerners or Southerners and should be kept where they belong. Still the metes and bounds of latitude may be set aside by such local modifications as hills, valleys, bodies of water, winds and sunshine. Fortunate is the man who has his orchards planted only with sorts suited to his latitude. Climate is the fruit grower's greatest asset and costs him nothing.

As with all crops, the soil must largely determine the value of a location for a fruit plantation and in choosing land all of the characters, as physical structure, richness, power to retain moisture and depth must be well considered. As everyone knows special fruits have special soil adaptation; the peach grows on sand; the plum on clay; apples and pears on loams. But the knowledge that the several fruits have adaptations to soils is far from sufficient. A man planting fruit should know that each individual variety of any fruit will do better in some soils than in others. The successful fruit grower will discover what these preferences are. The chemist and the soil physicist can help but little here; in most cases an actual test in the field is the only way of knowing whether a variety will or will not thrive in a soil. One property of the soil is too often neglected; namely, its heat retaining properties. The florist knows that the violet and carnation want cool soils but the rose must have bottom heat. Some fruits, as the peach and the grape, require warm soils; apples and pears will thrive in cooler

lands but in general, a cold, heavy, close soil is a poor one for any of the fruits.

With the location and land selected the next question is, What varieties shall I plant? This question we have touched upon in part in previous paragraphs and it only remains here to be said that out of the thousands of varieties of the several fruits even the few best ones may be most readily characterized by their faults, showing how necessary it is to make a careful choice of varieties. An intimate first-hand knowledge of varieties in his own locality is the only way by which a man can become competent to choose the sorts to plant. Look a little askance at novelties. An unbridled passion for "new creations" has been the downfall of many orchards.

It is about as difficult to select the trees of the several fruits as it is to make a choice of varieties. It is not of prime importance but it is true and therefore worth paying attention to that trees grown near home are somewhat better than those brought from a distance. It is necessary to look out in buying that trees are true to name, free from pests and that they still have the breath of life. It would seem that only the simple would need to be told this. But I speak within bounds when I say that there is scarcely a fruit grower the country over, big or little, who has not suffered at the hands of some unscrupulous tree-dealer in substituted varieties, through the introduction of some pest, or through buying dead or worthless trees. And the buyer can only "grin and bear it." It is better, if possible, that the fruit grower have his trees propagated from individuals of known good qualities with the hope that these qualities will be handed down. To do this it may be necessary for the grower to furnish buds or scions.

Unfortunately few fruit growers concern themselves with the kind of stocks their trees are worked upon. Yet this is a most important matter. Apples may be bought upon Paradise, Doucin, or home grown or French grown standards. Now the first two named are probably only suitable for the amateur and of the standards, those on the foreign seedlings are usually

much the better. Pears are grown as standards on French seedlings or as dwarfs on the Angers quince. The dwarfs are gradually going out of vogue. The peach should be worked upon seedlings from southern pits and not upon those from cannery seeds. Sour cherries on Mazzard stock are far superior to those on the Mahaleb stock, yet the latter is usually planted because easier for the nurseryman to grow and therefore cheaper for the cherry grower to buy — a geat mistake on the part of the grower, as trees on Mahaleb stock are dear at any price. Plums are grown upon several stocks and no one seems to know which are best for the several species of this fruit, the different types of soil, and the hundreds of varieties.

After the trees are on hand the vexed problem arises as to how the orchard is to be laid out — whether in squares, quincunxes, hexagons, with or without fillers, and as to distances apart. Only generalities can be given here. The first is that a system of squares is usually best because it permits the orchard operations to be carried on most readily. Both roots and branches will utilize all of the space. Second, fillers of fruits other than varieties of the species composing the permanent trees usually serve only to vex the soul. They greatly complicate orchard operations and under treatment meant primarily for the permanent trees they are neither "fish, flesh, fowl, nor good red herring." Fillers of quick bearing varieties of the same fruit, especially the apple, may often be used to advantage. Third, there should be as many "outside rows" as possible. I mean the trees should be far enough apart for each to develop in full its individuality for every fruit grower knows that the trees on the outside of his orchard produce most fruit; the reason is that they get most air, sunshine, wind, moisture and food. What better argument for wide planting?

A good deal is being said about sex in fruits and especially about the impotency of varieties whereby their fruits do not set well. My own opinion is that fruit does not set in this region for most part because of frosts, cold weather, rains and

heavy winds at blooming time, but still there are some varieties of pears, apples, grapes and plums at least that are self-sterile. The remedy is mixed planting of varieties that bloom at the same time. It is important that the fruit of all of the varieties planted have value as it is not worth while to encumber land with a sort fit only for a pollinator. Contrary to a very general notion the fruits themselves are not greatly changed, if at all, by cross-pollination.

Pruning is almost prehistoric in origin and is popularly supposed to be the kindergarten operation in fruit growing, yet as now practiced it is a hit-and-miss cutting, sawing, chopping and shearing out of shoots, twigs, branches and limbs, designated by such expressive terms as "cutting-back," "heading in," "dehorning," and "thinning out the wood." There must always be a difference in the details of pruning but there are a few general facts and principles which every fruit grower should have well by heart. These, briefly stated, run about as follows:

1st. Winter pruning increases the vigor of the plant.

2d. Summer pruning decreases the vigor of the plant.

3d. Root pruning decreases the vigor of a plant.

4th. Prune weak growing varieties heavily in the winter; strong growing sorts, lightly.

5th. Suckers or watersprouts are often the effect of over-pruning.

6th. Heading-in thickens the top.

7th. Checking growth by girdling, notching or twisting may induce fruitfulness but at the expense of vigor.

8th. Heavy pruning young trees delays fruiting.

9th. All pruning must take into account the habit of growth of the tree.

10th. Some fruits bear on this year's wood, others on that of last year, and still others on older growths; pruning must take the age of bearing wood into account.

A man can care for his trees better if he makes a sharp distinction between pruning and training trees. The operations of

pruning, as given above, have to do with the modification of the vigor and fruitfulness of the plants, but training, properly speaking, aims to keep the trees in manageable shape. Training, then, as to whether high-headed or low-headed, open-centered or close-centered, one-storied or two-storied, bush-shape or tree-shape, or according to the Kniffen-system, the fan-system, the horizontal or the vertical arm systems, depends largely upon the conveniences and the whims and prejudices of the grower. It is probably more important that a definite ideal be chosen and adhered to than that any particular choice be made.

Cultivation is very generally practiced with all fruits excepting the apple; some claim that this fruit in this State can be grown better in sod in which case the grass may be cut as a mulch or it may be kept down by sheep, pigs or cattle. The various modifications of the sod method of managing orchards have come to the fore because of the performance of a few individual orchards in the State. Unfortunately it is not yet known whether these orchards are the exception or the rule, that is whether or not they represent the average run of apple orchards in New York. Again, no one knows as yet whether these orchards would not have done better under tillage than under sod for results have not been given the public which show comparative data from the two methods in any of the orchards.

The New York Agricultural Experiment Station has two experiments to test these methods of orchard management. This year we are publishing on one of these experiments and a brief synopsis of the results may therefore be given here, the gravity of the issue before the apple growers of the State, warranting this premature setting forth of the data. The following are the chief results in a five-year experiment in the Auchter orchard: Annual average amount of fruit on 5 acres; sod, 340.2 bbls.; tillage, 509.7 bbls.; difference, 169.5 bbls. Annual acre average, sod, 68 bbls.; tillage, 101.9 bbls.; difference, 33.9 bbls. The difference in quantity is due both to a difference in number of fruits and in size of the specimens; for estimates of

percentage of blossoms show that the tilled trees bear more blossoms than the sod trees and a count of apples in barrels of first-class fruit show an average of 434 fruits in a barrel of sod-mulch fruit and 309 for the tilled fruit; or, an average weight of 5.01 ounces for the sod apples and 7.02 ounces for the tilled.

The one respect in which the sod-mulch fruit surpasses the tilled is in color. But since in every possible test the tilled trees are shown to be most vigorous, and since wounded, diseased, and decrepit trees always bear fruit of high color, it can be said that the bright color of the sod fruit is the hectic flush of disease or decrepitude.

The fruit on the sod-plat matures from two to three weeks earlier than that on the tilled land and there is even a greater difference in the length of time the apples from the two plats will keep.

The fruit from the tilled plat is crisper, juicier and better flavored, a fact many times affirmed by those in charge of the experiment and attested to by all of the many apple connoisseurs who have been asked to take a taste.

The growth of trees is more uniform on the tilled plat than on the sod and the crops on the trees, both as to size and quantity of fruit, are more uniform. In commercial orcharding it is greatly to be desired that trees behave uniformly.

In the long run the crop performance in an orchard measures vigor and health but in so short a period as five years we must know how the trees themselves are affected. The health and vigor of a tree is almost directly proportioned to the increase in the diameter of the trunk. The trees on the sod plat gained an average of 1.1 inches in diameter; on the tilled plat, 2.1 inches. This is as clear cut and as accurate evidence as can be offered.

The annual growth of new wood on an apple tree is a most important criterion because it measures both the vigor and the bearing capacity of the tree since fruit buds may be formed on any of the wood older than one year. The average annual

growth per branch on the sodded trees was 3.4 inches; tilled trees, 6.7 inches, the tilled trees making twice the growth made by those on sod.

The foliage of a tree is as ready a test and as delicate a one to determine health as the pulse is to a human being. The tell-tale tints of the leaves alone would convince even the most skeptical of the superior vigor and health of the tilled trees in this experiment but the size of leaves, amount of foliage, weight of foliage, total leaf area and length of time the leaves remain on the tree, all prove tillage the better method of orchard management to obtain health and vigor of tree.

Liebig's "law of the minimum," according to which the yield of a given crop will be limited by the amount of one particular constituent of food, if applied to all the factors affecting the trees in this orchard will show that one factor alone is quite sufficient to account for the differences noted — namely, the supply of water.

The results of 128 determinations of moisture in the top foot of soil show that in the 2,000 tons comprising the upper layer in an acre there were in the sod plat at any time from June to September 144.4 tons of water; in the tilled plat, 239.8 tons, or a difference of 95.4 tons, or 724 barrels or 23,483 gallons. These figures substantiate what is held by all soil authorities, that in this climate, conserve it and save as best you can, the seasonal rainfall on the average soil is not more than sufficient for the best development of any one crop; indeed it is seldom sufficient for one crop. If then, we divide the rainfall between two crops, grass and apples, both must suffer.

A brief financial statement regarding this experiment may be of interest since the claim is so often made that sod-mulch method is cheaper than tillage. The average cost per acre of the two methods of management were: for the sod, $17.92; tillage, $24.47; a difference of $6.55 per acre in favor of the sod-mulch. But the cost per barrel of apples, counting rental of land, was $1.65 for the tilled plat and $2.15 for the sod plat, $.50 per barrel in favor of tillage. It is not cheap methods that

give highest profits; lowest cost of production gives highest profits.

We pass now to another phase of orchard management — that of inter-crops and cover-crops. The best modern orchard practice permits the growing of inter-crops, hoed crops preferred, in an orchard until the trees come in bearing, and insists upon there being a cover-crop sowed at the close of the season's cultivation to be plowed under the following spring. The use of inter-crops and cover-crops in orchards gives a splendid opportunity for the study of the likes and dislikes of plants for some plants seem to be really particular as to the company they keep. For instance, there are observations and some experimental data to show that the peach and the potato will not break bread and sup together in peace and if grown in intimate contact the results are disastrous and most so to the peach. Much ill-feeling is manifest between the cereals and the peach; not so marked between the cabbage family and the peach; while members of the clover family are pleasant and profitable companions for Madame Peach. All this suggests that crops for the orchard must be chosen with some care. If an inter-crop is sown, keep tree and crop so separated that they can not trouble each other. In the use of a cover-crop to check growth, interference with the food and drink of the tree by the cover-top must be expected; and lastly, in the case of the legumes at least, a crop may be sown which will materially add to the food-supply of the trees themselves.

In the present-day fruit growing the horticulturist is not permitted to say much about insects, fungi and spraying. The botanist and the entomologist hold that the Almighty meant them in particular when he gave man dominion over "every creeping thing that creepeth upon the earth." While we shall have to admit that the knowledge and skill of the entomologist and botanist are indispensable, yet the fruit grower can so plant as to avoid some of the warfare with pests in which we are all now engaged. Thus King, Roxbury and Northern Spy among apples are nearly free from scale as are the Kieffer, LeConte and Winter Nellis pears, Niagara and Field plums and all sour

cherries. There are about thirty varieties of apples on the grounds of the New York Agricultural Experiment Station never injured by scab, as many more scarcely injured, and of course a large number that are badly injured. The Seckel, Kieffer, Le Conte and Winter Nellis pears do not blight badly. A few plums are never attacked by black-knot and some peaches are almost immune to peach curl. Now with these, and nearly all other pests, men who can not or will not spray, the general farmer and the city suburbanite, for example, should plant varieties measurably immune to the most troublesome pests.

Two thousand years ago Columella wrote "The earth neither grows old nor wears out if it be dunged." The truth is a general one and holds with fruits as with other plants. Few will gainsay the statement that if a fruit grower is to crop without crippling over a long period of years he must "dung the earth." Yet I do not believe that fruit crops require the addition of nearly as much fertilizer to the average soil in this State as do farm and truck crops. The basis for this statement comes from observation covering a number of years, the experience of many fruit growers, but more particularly from three experiments carried on at the New York Agricultural Experiment Station. I do not wish to discuss these experiments at this time but rather to set forth several theoretical considerations as to why fruits in general do not require the addition of as much plant food as farm crops.

1. From eighty to ninety per ct. of a fruit crop is water; the food used in the foliage is returned to the soil. The percentage of solid matter is much greater in farm crops.

2. Trees have a preparatory season of several years before they begin bearing. Farm crops come and go in a season.

3. The growing season for trees is long, from early spring to late fall. It is comparatively short for farm crops.

4. The roots go down and spread out in the case of tree fruits but are comparatively restricted with farm crops.

5. Trees transpire relatively large amounts of water and therefore relatively diluted solutions of plant-food may suffice to furnish food.

6. All tree fruits have "off years" in which to recuperate.

7. It is possible to give fruit trees more thorough cultivation, thereby better conserving moisture and making food more available, than in the case of farm crops.

It does not follow from what has been said that tree-fruits never need fertilizers but these considerations make it plain that exceedingly great care must be used in feeding trees if it is to be done without waste. The fruit grower ought to experiment very carefully to see that he gets the worth of his money before using any considerable quantities of fertilizers in an orchard.

Lastly, the fruit grower, of all tillers of the soil, should know the plants he works with; should have an insight into their life processes; should know how they are affected by external conditions; should understand the more or less distinct individuality of each of his trees. Fruit plants are various in kind and trees of one kind are often quite unlike because the conditions under which they are grown are dissimilar; and because plants are inherently variable and plastic. It follows, then, that conditions must vary for every person who grows fruit and that there must therefore be more or less diverse ideals, diverse methods and diverse results. But certain forces, embraced in what we call "good care" have brought all fruits from the wild to their present state of domestication, and these forces modified and refined as we gain new knowledge, must be kept in constant operation.

DWARF APPLES.*

U. P. HEDRICK.

Dwarf apples are of recurrent interest in the United States. Nearly a hundred years ago pomological literature shows that they began to receive more or less attention in America. At several periods since that time fruit growers have shown unusual interest in the subject, and plantations of dwarf apples have been made. We are now in the midst of one of these periodic revivals. Several prominent fruit growers recommend the growing of apples on dwarf stock; a book has been written on the subject; a number of experiment stations are trying the dwarfing method, and the horticultural press is telling "Why You Should Grow Dwarf Apples."

Especial interest in dwarf apples began at the New York Agricultural Experiment Station in 1991, when the *State Fruit Growers' Association, The Eastern New York Horticultural Society,* and *The Western New York Horticultural Society* appointed committees to confer with the authorities at the Station for the purpose of locating experimental orchards of dwarf apples. It is well to state here and to emphasize the motive which led these societies and the Station to co-operate in the planting of these dwarf trees.

San José scale had invaded the State and was rapidly spreading. It was known that it could not be exterminated, and it was feared that it could not be controlled. It was thought at that time that the scale could be best controlled by fumigating the trees under tents, and it was believed that full grown, standard trees could not be thoroughly sprayed. Since it was certain that dwarf trees could be easily fumigated and thoroughly sprayed, fruit growers asked for an experiment to determine whether dwarf trees could be grown profitably in commercial orchards. Had it not been for the bugaboo, San José scale, it is doubtful if the fruit growers would have called

*A reprint of Circular No. 12.

for the investigation, or the State have voluntarily undertaken it.

Three sites were chosen for experiments: One at Kinderhook, in the Hudson Valley, on the farm of Edward Van Alstyne; another at Fayetteville, Onondaga county, on the farm of F. E. Dawley, and the third at Carlton, Orleans county, on the farm of Albert Wood & Son. The trees in these orchards were to be budded on three stocks, and this leads to a consideration of the whole matter of stocks.

Several kinds of dwarf apples are used as stocks upon which to bud or graft free-growing apples to dwarf them. These have been used in Europe probably for several centuries, and from the experience two kinds have been selected as having preeminent merit as dwarfing stocks; one the Paradise — the other the Doucin.

Paradise stocks.— Of the two stocks, the Paradise makes the smaller tree, and is sometimes called the "Dwarf Apple" — the Doucin, the "Half Dwarf Apple." The effect of grafting the common varieties on Paradise stock is a very diminutive or bush-like apple tree. These stocks are grown in Europe, mostly in France, and very largely by means of mound layers, a fact which indicates that the plant is inclined to stool or sucker, often forming, when left to mature, a true bush. This stock is also extremely shallow-rooted, and needs much fertility in the soil, and still more an abundance of moisture. Not all varieties of apples thrive on Paradise roots, scions of many failing to make perfect unions. The Northern Spy, Ben Davis, Baldwin and R. I. Greening seem to be examples. The union is very poor with nearly all varieties unless the tree is trained to some style of dwarf head. The considerations of food, moisture, union and training make it necessary to give apple trees on Paradise stocks very careful attention.

Doucin stocks.—The Doucin stock produces a tree about midway between the Paradise dwarf and the common standard tree. Nearly all varieties of apples are thought to produce a good union with this stock, though we are not finding this

quite true in our experiments. Its food and moisture requirements seem to differ but little from those of the standard trees, though without doubt they should receive much more attention in training. With both of these dwarfing stocks it is necessary to make sure that the scion does not throw out roots and give what is called a "bull" tree. Unfortunately the scion may root at any time from setting to maturity. Doucin stocks are also brought from Europe and if from England care must be exercised as to the name of the stock ordered; for the English call the Doucin stock "Broad leaved Paradise," and the true Paradise "French Paradise." This confusion in names has caused much trouble in ordering, and without doubt there are many plantations in America on stocks wrongly named.

Standard stocks.— Since practically all of our apples are now on this stock all are familiar with it and little need be said of it here. The trees upon which apples are grafted or budded for standard trees come from France for the most part, and are called "French Crabs," the word crab being used in the sense of a wild or inferior tree, not necessarily the true crab-apple. These stocks are grown from seeds and are imported to America in great numbers. Some standard stocks are grown in America and are known to the trade as "domestic stocks." These are not looked upon as being as uniform in growth, as hardy or as vigorous as the French Crab, and for Eastern America, at least, are not as cheap. All varieties of apples make good unions with standard stocks.

Advantages of dwarf apples.— In Europe dwarf apples have a number of advantages over the standard trees. Advocates of the smaller trees claim the same advantages for the dwarfs in America. It is very doubtful if these hold on the two continents to the same degree, yet they may be set forth here.

1. Dwarf trees, especially those on Paradise stock, come in bearing earlier than standards.
2. All orchard operations are more easily performed.
3. Winds cause less injury to the trees and crops.

4. The small size of dwarf trees permits the planting of a greater number of varieties on a given area.

5. The fruit from dwarf trees is of higher quality as to size, color and flavor.

We are now ready to see how the experiments by the Geneva Station so far justify these claims.

THE ORCHARDS.

The Van Alstyne orchard contains 306 trees distributed among the three stocks as follows: Standard trees, 27; on Doucin stock, 153 trees; on Paradise, 126. These were distributed among the following varieties: Baldwin, Boiken, Holland, Hubbardston, Jonathan, Lady, McIntosh, R. I. Greening, Rome, Sutton, Wealthy and Wagener.

The Dawley orchard is planted with 512 trees, the number on each stock being: Standards, 42; Doucin, 161; Paradise, 309. The following are the varieties: Alexander, Baldwin, Boiken, Esopus, Gravenstein, Green Sweet, Grimes, Hubbardston, Jacob Sweet, Jonathan, Longfield, McIntosh, Monmouth, Northern Spy, Pumpkin Sweet, R. I. Greening, Rome, Sutton, Wagener, Wealthy, Wolf River and Yellow Transparent.

In the Wood orchard there are 300 trees: Forty-five on standard, 90 on Doucin and 165 on Paradise stocks, distributed among the following varieties: Alexander, Baldwin, Ben Davis, Boiken, Gravenstein, Jonathan, Holland Winter, McIntosh, Monmouth, R. I. Greening, Rome, Sutton, Lady, Bismark, Twenty Ounce and Wealthy.

The trees for the three orchards were budded in July 1902, the Wood orchard being set in the fall of 1903, and the other two a year later. The disproportionate number for the three stocks is due to the desire to leave in the end permanent orchards of the three stocks standing the proper distance apart, and yet make the best use of the land during the time the trees are coming to maturity. In other words, the trees are arranged in the filler system of planting. The distance apart in the Wood orchard is fifteen feet — in the other two, twelve feet.

Taking up the several claims for dwarf trees, we have to discuss first early bearing. The following are the combined yields for the several years in the three orchards:

The first year after planting — trees three years from the bud — one apple was borne by a Boiken on a Paradise stock. The second year after planting, the 602 Paradise trees in the three orchards bore 237 apples, Boiken, Ben Davis, Wealthy and Wagener producing the crop. The 444 Doucin trees bore twenty-one apples, distributed among nearly as many varieties. The 114 standard trees bore no apples this second year. These figures give an average of less than half an apple to the tree for the Paradise stock, hardly justifying the oft-made assertion that trees on this stock bear paying crops the second year from planting. The third year the Paradise trees bore in the three orchards an average of 1.6 apples per tree. The Doucin stock an average of a little over a half apple per tree. The 114 standard trees this year bore two apples. In 1908, the fourth year from setting, the Paradise trees bore an average of 5.7 apples per tree; the Doucins 1.8 apples; the Standards this year bore nearly a third of an apple per tree. The fifth year from setting the 602 Paradise trees bore 12.7 apples per tree; the 444 Doucins bore a fraction less than six apples per tree and the 114 Standards produced a half apple per tree.

These figures are for the combined orchards and for all varieties. If we separate the orchards the figures are changed somewhat, because of the changed natural condition under which the trees are growing. The Van Alstyne orchard had no apples until the third year after setting, and then but three, one of which was on a standard, and the other two on Doucin. The fourth and fifth year it bore small crops, the proportion of the crop being about the same for the three stocks. In this orchard the Paradise trees are not coming in bearing earlier than even the standards. In the Dawley orchard the Doucin trees came in bearing with the Paradise trees, but for the past two seasons have been more productive, though the difference is within the range of chance variation. It is only in the Wood

orchard that the Paradise trees have come in bearing appreciably earlier than the apples on the other two stocks. But even here the crop was not large enough to cut any financial figure, until the present season, the fifth from setting, when the average for the 165 trees was about one-third of a bushel, with about half as much on the Doucin trees and almost nothing on the standard stocks.

If varieties are compared there is a tremendous variation. Boiken, Ben Davis, Wealthy, Wagener, Longfield, Rhode Island Greening, and Rome, about in the order named, have been the largest bearers, while Sutton, Northern Spy and Twenty Ounce have not yet started to bear on any of the stocks.

These figures show that while apples on Paradise stock come in bearing earliest, they do not bear profitable crops, as is so often stated, two years from planting, and only in one of the three orchards could there have been any financial return from the varieties on Paradise until the fifth year.

As to the claim that orchard operations are easier in dwarf orchards it is apparent at once that such is the case for nearly all operations, yet there are exceptions that in these days of first-class orchard equipment nearly off-set the greater ease with which dwarf trees may be sprayed and the fruit thinned and pruned. I refer to cultivation and pruning. The close planting and low heading in dwarf orchards make it difficult to cultivate properly and to some extent to get about at all in the orchard. In pruning the work with dwarf trees is vastly greater. Not only must there be the usual winter pruning, but also a much more painstaking and laborious summer pruning coming at a time when help can be illy spared. Moreover each season it is necessary to dig about the trees to see that the scions are not taking root. In these experiments it has been found much more difficult to train the dwarf trees with good heads than to similarly shape standard trees.

Coming to the third claim for dwarf trees — that wind does less damage to trees and crops — this experiment demonstrates nothing. From observation it is certain, however, that the loss

from gales in a windy country and high-headed trees is greater. The difference between dwarf and low-headed standard trees, however, in this respect is almost a negligible factor. If standard and Paradise trees are compared the difference is in favor of low-headed standards for in the orchards under consideration it was found that the shallow-rooted Paradise trees often blew over.

The fourth claim of merit is as to the small size whereby more dwarf trees can be planted on a given area. This is an advantage for amateurs who have little room and want many varieties, and to the fruit grower who may want to test varieties. These three orchards demonstrate very plainly, however, that the enthusiasts who are recommending for America a distance of anywhere from six to twelve feet for Paradise stock and eight to sixteen for Doucin, are putting them far too close together. In America these distances will have to be doubled unless the soil, trees and methods are very different from those in these experiments or in the many orchards that have come under the writer's observation.

The claim in regard to greater size, higher color and better flavor for the fruit of dwarf trees, is one most often made, and yet in these three orchards we have been badly disappointed in these regards. Where comparisons have been possible the fruit from dwarf trees has been no better in size and flavor than that from standard trees, or that to be found in many orchards of the same size and varieties in different parts of the State. Whether this will continue indefinitely remains to be seen, but certainly up to the present there has been little to justify the claim for better quality from dwarf trees.

The work in these orchards brings out several marked disadvantages of dwarf trees. The first is that the trees are more expensive than standard trees. It costs more to propagate and grow them and the nurserymen must get more for them. A second is that there is now and has been for generations a dispute as to what the true Paradise and the true Doucin stocks

are. When to this confusion is added the disposition of some nurserymen to substitute, those who have had experience in buying trees know well what the possibilities are of getting the right variety on the right stock. Third, as we have pointed out in one or two particulars, dwarf trees need more care. This applies to all particulars. The loss of dwarf trees by death, from one cause or another in these three orchards is much greater than in orchards of all standards. Fourth, while this test of dwarf trees does not prove it, all concede that such trees are much shorter lived than standard trees. How much shorter cannot be said without more definite data than can now be found.

In conclusion, while this experiment is not nearly finished, it is apparent to all who have been working with the orchards that dwarf apples will not take the place of standard apples in commercial orchards. Whether they can be profitably used as fillers with standard trees is a question. The writer would prefer standard trees as fillers. It may be that some varieties can be profitably used as dwarf fillers. Possibly a few sorts may be used in limited numbers for a commercial orchard of dwarfs. The only place for dwarf trees at present seems to be, under some conditions, in the garden of the amateur.

The many inquiries in regard to these dwarf orchards and the keen popular interest now manifested in regard to dwarf trees is the excuse for the discussion of an experiment not yet completed.

INSPECTION WORK.

REPORT OF ANALYSES OF SAMPLES OF FERTILIZERS COLLECTED BY THE COMMISSIONER OF AGRICULTURE DURING 1909.*

(The analyses reported in these Bulletins cease to have value long before they could be reprinted in this Report; and are, therefore, omitted.—W. H. Jordan, *Director.*)

INSPECTION OF FEEDING STUFFS.†

(See note above. Some comments on results of feeding stuffs inspection will be found in the Director's report (page 27 of this volume).— W. H. Jordan, *Director.*)

* Printed as Bulletin No. 318.
† Printed as Bulletin No. 316.

APPENDIX.

I. Periodicals Received by the Station.

II. Meteorological Records.

PERIODICALS RECEIVED BY THE STATION.

Acclimitation	Complimentary
Agricultural Epitomist	Complimentary
Agricultural Gazette of New South Wales	Complimentary
Agricultural Journal and Mining Records (Natal)	Complimentary
Agricultural Journal of the Cape of Good Hope	Complimentary
Agricultural Ledger	Complimentary
Agricultural News	Complimentary
Allegan Gazette	Complimentary
American Agriculturist	Subscription
American Chemical Journal	Subscription
American Chemical Society, Journal	Subscription
American Cultivator	Complimentary
American Entomological Society, Transactions	Subscription
American Fertilizer	Subscription
American Florist	Subscription
American Grocer	Complimentary
American Hay, Flour and Feed Journal	Complimentary
American Journal of Physiology	Subscription
American Miller	Complimentary
American Naturalist	Subscription
American Philosophical Society, Proceedings	Complimentary
American Poultry Advocate	Complimentary
American Poultry Journal	Complimentary
American Poultry World	Subscription
American Stock Keeper	Complimentary
American Sugar Industry and Beet Sugar Gazette	Complimentary
Analyst	Subscription
Annales de l'Institut Pasteur	Subscription
Annales de la Societe Entomologique de Belgique	Complimentary
Annales Mycologici	Subscription
Annals of Botany	Subscription
Archiv der Gesammte Physiologie (Plfueger)	Subscription
Archiv fuer Hygiene	Subscription
Association Belge des Chimistes, Bulletin	Complimentary
Australian Garden and Field	Complimentary

Beet Sugar Gazette	Complimentary
Berichte der deutschen botanischen Gesellschaft	Subscription
Berichte der deutschen chemischen Gesellschaft	Subscription
Better Fruit	Complimentary
Biedermann's Zentralblatt fuer Agrikultur Chemie	Subscription
Biochemische Zeitschrift	Subscription
Biochemisches Centralblatt	Subscription
Biological Bulletin	Subscription
Biologisches Centralblatt	Subscription
Biometrika	Subscription
Biophysikalisches Centralblatt	Subscription
Blooded Stock	Complimentary
Boletim de Agricultura	Complimentary
Boletim do Instituto Agronomico	Complimentary
Boletin de la Sociedad Nacional de Agricultura	Complimentary
Boletin de Ministero de Frumento	Complimentary
Boston Society of Natural History, Proceedings	Subscription
Botanical Gazette	Subscription
Botanische Zeitung	Subscription
Biologisches Centralblatt	Subscription
Botaniste, Le	Subscription
Buffalo Society of Natural Sciences, Bulletin	Complimentary
Bulletin of the Department of Agriculture, Jamaica	Complimentary
Caledonia Era	Complimentary
California Cultivator	Complimentary
California Fruit Grower	Subscription
California University Publications — Botany	Complimentary
Canadian Entomologist	Subscription
Canadian Horticulturist	Complimentary
Centralblatt fuer Bakteriologie, etc	Subscription
Chemical Abstracts	Subscription
Chemical Society, Journal	Subscription
Chemisches Centralblatt	Subscription
Chicago Daily Farmers' and Drovers' Journal	Complimentary
Chicago Dairy Produce	Complimentary
Cincinnati Society of Natural History, Journal	Complimentary
Cold Storage and Ice Trades Review	Complimentary
Colman's Rural World	Complimentary
Colonial Dairy Produce Report	Complimentary
Columbus Horticultural Society, Journal	Complimentary
Commercial Poultry	Complimentary
Country Gentleman	Subscription

Country Life in America	Subscription
Country World	Complimentary
Dairy and Produce Review	Complimentary
Elgin Dairy Report	Complimentary
Elisha Mitchell Scientific Society, Journal	Complimentary
Entomological News	Subscription
Entomological Society of Washington, Proceedings	Subscription
Entomologische Zeitschrift	Subscription
Entomologist	Subscription
Entomologists' Record	Subscription
Farm and Fireside	Complimentary
Farm and Live Stock Journal	Complimentary
Farm and Stock	Complimentary
Farm Journal	Complimentary
Farm Life	Complimentary
Farm News	Complimentary
Farm Poultry	Complimentary
Farm, Stock and Home	Complimentary
Farm Stock Success	Complimentary
Farmers' Advocate	Complimentary
Farmers' Call	Complimentary
Farmers' Guide	Complimentary
Farmers' Voice	Complimentary
Feather	Subscription
Feathered World	Subscription
Florists' Exchange	Subscription
Flour and Feed	Complimentary
Flour Trade News	Complimentary
Fruit Grower	Complimentary
Fruitman and Gardener	Complimentary
Garden	Subscription
Garden Magazine	Subscription
Gardeners' Chronicle	Subscription
Gardeners' Chronicle of America	Complimentary
Gardening	Subscription
Gartenwelt	Subscription
Gas and Oil Power	Complimentary
Gleanings in Bee Culture	Complimentary
Green's Fruit Grower	Complimentary
Hartwick Seminary Monthly	Complimentary
Hawaiian Forester and Agriculturist	Complimentary
Hedwigia	Subscription

Herd Register	Complimentary
Hoard's Dairyman	Complimentary
Holstein-Friesian Register	Complimentary
Holstein-Friesian World	Complimentary
Homestead	Complimentary
Hygienische Rundschau	Subscription
Indiana Farmer	Complimentary
Insect World (Japanese)	Complimentary
Ithaca Chronicle	Complimentary
Jahresbericht der Agrikultur-Chemie	Subscription
Jahresbericht Garungs-Organismen	Subscription
Jahresbericht der Nahrungs-und Genussmittel	Subscription
Jahresbericht Pflanzenkrankheiten	Subscription
Jahresbericht der Tier-Chemie	Subscription
Jahresheft Schlesische Insektenkunde	Complimentary
Jersey Bulletin	Complimentary
Journal of Agricultural Science	Subscription
Journal of Agriculture, Victoria	Complimentary
Journal of Biological Chemistry	Subscription
Journal of Board of Agriculture (English)	Complimentary
Journal de Botanique	Subscription
Journal of the College of Agriculture, Tokyo	Complimentary
Journal of the Dept. of Agriculture of Western Australia.	Complimentary
Journal of Economic Biology	Subscription
Journal of Experimental Medicine	Subscription
Journal of Experimental Zoology	Subscription
Journal fuer Landwirtschaft	Subscription
Journal of Physiology	Subscription
Just's Botanischer Jahresbericht	Subscription
Kimball's Dairy Farmer	Complimentary
Lanswirtschaft-Historische Blätter	Complimentary
Landwirtschaftlicher Jahrbucher	Subscription
Landwirtschaftlicher Jahrbuch der Schweiz	Subscription
Landwirtschaftlichen Versuchs-Stationen	Subscription
Live Stock and Dairy Journal	Complimentary
Live Stock Report	Complimentary
Long Island Democrat	Complimentary
Market Fruit-Growers' Journal	Complimentary
Marlboro Record	Complimentary
Memoirs of the Department of Agriculture in India	Complimentary
Metropolitan and Rural Home	Complimentary
Michigan Farmer	Complimentary

Milch Zeitung	Subscription
Milchwirtschaftliches Zentralblatt	Subscription
Minnesota and Dakota Farmer	Complimentary
Mirror and Farmer	Complimentary
Modern Farming	Complimentary
Monthly Weather Review	Complimentary
Mycologia	Subscription
National Nurseryman	Complimentary
National Farmer and Stock Grower	Complimentary
National Grange	Complimentary
National Stockman and Farmer	Complimentary
Naturaliste Canadienne	Complimentary
Nebraska Farmer	Complimentary
New England Farmer	Complimentary
New York Academy of Science, Annals and Transactions	Subscription
New York Botanical Garden, Bulletin	Complimentary
New York Entomological Society, Journal	Subscription
New York Farmer	Complimentary
New York Fruit and Produce News	Complimentary
New Zealand Dairyman	Complimentary
North American Horticulturist	Complimentary
Northwest Pacific Farmer	Complimentary
Nut Grower	Complimentary
Ohio Farmer	Complimentary
Ohio Naturalist	Subscription
Pacific Coast Fanciers' Monthly	Subscription
Pennsylvania Farmer	Complimentary
Photo-Miniature	Subscription
Pacific Fruit World	Complimentary
Parasitology	Subscription
Popular Agriculturist	Complimentary
Poultry	Complimentary
Poultry Herald	Subscription
Poultry Husbandry	Complimentary
Poultry Industry	Complimentary
Poultry Keeper	Complimentary
Poultry Monthly	Complimentary
Power and Engineer	Subscription
Practical Dairyman	Complimentary
Practical Farmer	Complimentary
Practical Fruit Grower	Complimentary
Praktische Blaetter fuer Pflanzenschutz	Subscription
Progressive Farmer	Complimentary

Psyche	Subscription
Rabenhorst's Kryptogamen-Flora	Subscription
Reliable Poultry Journal	Subscription
Républic	Complimentary
Révue Generale de Botanique	Subscription
Revue Generale du Lait	Subscription
Revue Horticole	Subscription
Revue Mycologique	Subscription
Royal Agricultural Society, Journal	Subscription
Royal Horticultural Society, Journal	Subscription
Rural New Yorker	Subscription
Salt Lake Herald	Complimentary
Saint Louis Academy of Science, Transactions	Complimentary
Sanitary Inspector	Complimentary
Science	Subscription
Scientific American	Subscription
Scientific Roll, Bacteria	Subscription
Skaneateles Democrat	Complimentary
Society of Chemical Industry, Journal	Subscription
Societe Entomologique Belgique, Annales	Complimentary
Societe Entomologique de France, Bulletin	Complimentary
Societe Mycologique de France, Bulletin	Subscription
Southeast Missouri Farm, Fruit and Poultry	Complimentary
Southern Planter	Complimentary
Southern Tobacconist and Modern Farmer	Complimentary
Southern Farm Magazine	Complimentary
Southwestern Farmer and American Horticulturist	Complimentary
Southwestern Farmer and Breeder	Complimentary
Station, Farm and Dairy	Complimentary
Stazione Sperimentali Agrarie Italiane	Complimentary
Student Farmer, The	Complimentary
Successful Farming	Complimentary
Suffolk Herald	Complimentary
Sugar Beet	Complimentary
Texas Stockman and Farmer	Complimentary
Torrey Botanical Club, Bulletins and Memoirs	Subscription
Transvaal Agricultural Journal	Complimentary
Up-to-Date Farming and Gardening	Complimentary
Utica Semi-Weekly Press	Complimentary
Wallace's Farmer	Complimentary
West Indian Bulletin	Complimentary
West Virginia Farm Review	Complimentary

Western Fruit-Grower	Complimentary
Western Plowman	Complimentary
Zeitschrift fuer Analytische Chemie	Subscription
Zeitschrift fuer Biologie	Subscription
Zeitschrift fuer Hygiene und Infektions-Krankheiten	Subscription
Zeitschrift fuer Pflanzenkrankheiten	Subscription
Zeitschrift fuer Physiologische Chemie	Subscription
Zeitschrift fuer Untersuchung der Nahrungs and Genus-mittel	Subscription
Zoological Record	Subscription
Zoologischer Anzeiger	Subscription

METEOROLOGICAL RECORDS FOR 1909.

METEOROLOGICAL RECORDS FOR 1909.

READING OF MAXIMUM AND MINIMUM THERMOMETERS FOR 1909.

DATE.	January.		February.		March.		April.		May.		June.	
	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.
1	28.	20.	17.	—1.	35.5	5.5	50.	31.5	55.	35.	78.	49.
2	36.	18.	32.	12.	40.	30.	46.	28.	44.	33.	81.	56.
3	40.5	28.	27.	10.	39.	25.	48.	31.5	52.	33.	83.	58.
4	50.	38.	39.	9.	38.	21.	52.	31.	56.	34.	80.	56.
5	50.	41.	52.	36.	25.	5.	66.	34.	69.	37.	74.	61.
6	34.	18.	50.	30.	39.	11.	72.	49.	72.	51.	69.	54.
7	11.	7.	37.	26.	40.	29.	72.	38.	70.	47.	67	56.
8	24.5	1.	35.	22.	36.	21.	51.	34.	71.5	38.	70.	43.
9	32.	17.	25.	9.5	42.	21.	48.	29.	77.	55.	64.	53.
10	38.	30.	41.	24.	52.	35.	34.	21.	67.	38.	60.	54.
11	44.	23.	30.	17.	38.	20.	44.	12.	57.	35.5	75.5	55.
12	20.	14.	45.	17.	41.	24.	61.	34.	68.	41.	80.	50.
13	22.	—2.	44.	26.	37.	27.	69.	46.	77.5	42.	78.	57.
14	35.	12.	27.	23.	35.5	22.	63.	32.	73.	46.	79.	61.
15	43.	12.	26.	17.	34.	26.	49.	32.	70.	50.	73.	51.
16	23.	3.	23.	17.	37.	23.	59.	30.	74.	56.	79.	46.
17	26.5	9.	29.	15.	36.	11.	60.	47.	67.	49.	78.	52.
18	26.	2.	29.5	23.	37.	19.	73.	37.	63.	46.	67.	45.
19	32.	—7.	45.	26.	35.	22.	75.	43.	68.	41.	75.	47.
20	39.	26.	44.	33.	39.	28.	48.	35.	69.	48.	84.	49.
21	45.	25.	35.	28.	32.	21.	48.	39.	65.	49.	89.	56.
22	51.	39.	50.	26.	34.	22.	57.	42.	58.	48.	85.	60.
23	49.	39.	40.	25.5	43.	23.5	55.	40.	65.	45.	88.	53.
24	64.	43.	51.	28.	47.	24.	45.	29.	73.	44.	89.	67.
25	62.	34.5	40.	13.	44.	30.	62.	27.	71.	45.	89.	68.
26	38.	30.5	38.	14.	33.	26.	56.	31.	74.	38.	87.	64.
27	39.	25.	40.	30.	44.	25.	54.	29.	71.	50.	87.	59.
28	33.	19.	31.	20.	45.	32.	52.	28.	67.5	57.	90.	67.
29	29.	11.	......	......	41.	29.	39.	27.	77.	51.	89.	60.
30	28.	12.	......	......	41.	30.	55.	32.	76.	52.	89.	51.
31	20.	8.	......	......	47.	32.	......	......	78.	46.	......	......
Monthly averages	35.9	19.5	36.5	20.6	38.9	23.2	55.4	33.3	69.8	46.	79.2	55.3

READING OF MAXIMUM AND MINIMUM THERMOMETERS FOR 1909 — (*Concluded*).

DATE.	JULY.		AUGUST.		SEPTEMBER.		OCTOBER.		NOVEMBER.		DECEMBER.	
	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.	5 P. M. Max.	5 P. M. Min.
1	88.	69.	82.	57.	71.	42.	53.5	46.	73.	46.	43.	22.
2	82.	59.	86.	50.	72.	35.	57.	43.	69.	56.	41.	25.
3	68.	54.	87.	62.	84.	52.	55.	48.	67.	53.	41.	29.
4	71.	42.	84.	57.	80.	51.	63.	47.	58.	38.	35.	30.
5	78.	49.	89.	55.	68.	41.	68.	37.	46.	34.	43.	30.
6	80.	50.	87.	56.	75.	35.	71.	39.	52.	28.	45.	33.
7	80.	48.	92.	57.	75.	39.	74.	42.	54.	26.	37.	25.
8	83.	54.	98.	57.	78.	42.	77.5	44.	58.5	44.	29.	20.
9	83.	46.	85.	70.	83.	48.	82.5	46.	50.	31.	27.	7.
10	89.	58.	82.	62.	72.	60.	79.	50.	51.	33.	27.	14.
11	89.	66.	78.	51.	71.	57.	70.	58.	75.	43.	27.	22.
12	85.	65.	84.	48.	75.	43.	44.	52.	72.	48.	24.	15.
13	85.	70.	85.	59.	84.	60.	39.	32.	61.	43.	41.	23.
14	85.	57.	82.	62.	93.	63.	56.	34.	61.5	43.	42.	34.
15	92.	61.	80.	59.	87.	66.	51.	38.	67.	48.	35.	32.
16	75.	65.	78.	62.	75.	57.	50.	37.	50.	32.5	32.	25.
17	78.	62.	72.	56.	77.	47.	51.	39.	54.	33.	37.	22.
18	74.	53.	69.	57.	92.	63.	48.	34.	36.	25.	28.	21.
19	74.	52.	82.	60.	80.	72.	45.	33.	39.	25.	26.	17.
20	80.	55.	80.	62.	86.	69.	53.	33.	59.	35.	23.	16.
21	81.	49.	69.	53.	85.	53.	55.	30.	60.	45.	26.	19.
22	72.	60.	78.	44.	81.	60.	54.	46.	61.	37.	26.	17.
23	76.	60.	87.	52.	85.	62.	49.	38.	30.	26.	32.	21.
24	72.	58.	89.	58.	66.	49.	41.	35.	29.	21.	32.	28.
25	81.	48.	93.	62.	67.	42.	48.	32.	30.	23.	31.	25.
26	86.	55.	85.	69.	64.	44.	61.	33.	39.	27.	28.	21.
27	87.	60.	83.	59.	61.	46.	54.	45.	46.	28.	26.	13.
28	91.	61.	88.	49.	61.	39.	45.	33.	59.	37.	25.	10.
29	89.	69.	88.	74.	71.	40.	38.	27.	59.	31.	21.	3.
30	88.	72.	75.	51.	66.	47.	45.	27.	41.	24.	11.	1.
31	87.	58.	75.	32.	....	....	71.	35.	....	....	25.	6.
Monthly averages	81.6	57.6	83.	56.9	76.2	50.8	56.4	39.1	53.5	35.5	31.2	20.2

Readings of the Standard Air Thermometer.

DATE.	January.			February.			March.			April.			May.			June.		
	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.
1	21.	24.	23.	1.	9.	14.	11.	27.	34.	36.	48.	45.	43.	36.	44.	64.	74.5	73.
2	23.5	33.	30.	26.	24.	25.	36.	35.	35.	31.5	33.5	40.	39.	42.5	39.	60.	78.	78.
3	36.	39.	40.	18.	25.	24.	28.	37.	37.	33.5	41.5	41.	43.	51.	47.	67.	80.5	80.
4	42.	49.	45.	12.	36.	39.	22.	22.	25.	35.	41.5	48.	40.	52.	49.	62.	70.	65.
5	45.	48.	47.	40.	46.	46.5	12.	17.	21.	39.	57.	63.	44.	59.	70.	63.	68.	64.
6	34.	26.	19.	43.	37.	33.	15.	35.	39.	52.	67.	58.	63.	64.	63.	57.	64.5	66.
7	9.	10.5	8.	27.	36.	35.5	32.5	36.	35.	57.	62.	50.	58.	67.5	58.	59.	66.	61.
8	2.5	19.	24.5	31.5	27.	22.	24.	33.5	31.	36.	45.5	48.	50.	61.	69.	60.	69.	65.
9	25.	30.	31.5	10.5	20.	25.	28.	36.	42.	30.	37.5	34.	63.	71.	65.	55.5	59.5	58.
10	34.	38.	37.5	29.	36.	29.	43.	44.	36.	24.	28.5	24.	63.	54.5	48.	56.	55.	60.
11	36.	30.5	24.	22.	24.5	23.	21.	23.5	28.	23.	34.	43.	38.	51.	56.	58.	73.	75.5
12	14.	17.	17.	19.	36.	43.	27.	36.	37.	40.	55.	56.	52.	65.	65.	63.	77.	77.
13	0.	22.	15.	40.	33.	27.	29.	33.	32.	55.5	66.5	63.	49.	73.	72.5	64.	72.	64.
14	24.	31.	35.	24.	26.	26.	26.	35.	30.	35.	37.	37.	64.	72.	70.	71.	76.	73.
15	33.	33.5	23.	18.	18.5	19.	27.	32.5	32.	34.	45.	47.	51.	62.	68.	54.	66.	69.
16	4.	8.	11.	18.	21.	21.	27.	35.5	35.	40.	54.5	57.	64.	72.	67.	59.	74.	77.
17	14.	22.	26.	19.	24.	28.	21.	27.	25.5	50.	55.	55.	52.	52.	54.	68.	77.	67.
18	4.	5.	2.	27.	25.	29.	23.	33.	35.	46.	60.	70.	49.	58.	60.	49.	54.	59.
19	6.	20.	32.	37.	44.	41.	33.5	33.	34.	49.	69.	44.5	56.5	62.	64.	54.	71.	75.
20	30.	36.	30.	36.	36.	34.	33.	31.	32.	37.	45.5	47.	57.	68.	65.	65.	80.	84.
21	34.	41.	45.	29.	34.	33.	24.	29.	28.	41.5	45.	48.	51.	57.5	58.	69.	87.	85.
22	41.	47.	48.	33.	45.5	39.	27.	29.	30.5	44.	51.	54.	49.	51.5	56.	71.	72.	78.
23	43.	48.	47.	32.	37.	39.	26.	38.	40.	41.	46.	45.	53.	59.	64.	68.	86.	84.
24	48.	63.	57.	43.	49.	39.	30.	45.	38.	34.	41.	42.	56.	67.5	71.	76.	85.	86.
25	39.	38.	38.	20.	21.	20.	41.	33.	31.	33.	61.	55.	54.	68.	61.	77.	86.	85.
26	33.	32.	33.	19.	29.	36.	28.	31.	33.	33.	37.	41.	56.	68.	70.	73.	83.	84.
27	33.	38.	33.5	33.	39.5	30.5	33.	36.	43.	39.	49.	52.	60.	66.	63.	71.	84.	87.
28	21.	22.	23.	25.	24.	21.	35.	39.	36.	30.	37.5	38.	60.	67.5	59.	71.	87.	88.
29	22.	25.	28.	......	......	......	30.5	37.	37.5	32.	31.	34.	55.	68.	76.	69.	79.	75.
30	23.	21.	17.	......	......	......	32.	35.	34.	40.	50.	55.	60.	68.	73.	66.	83.	88.
31	12.	10.	9.	......	......	......	34.	43.	45.	......	......	......	65.	76.	76.	......	......	......
Monthly averages	25.4	29.9	29.	26.5	30.8	30.1	27.7	33.5	33.9	38.4	47.7	47.8	55.2	63.7	64.	64.	74.6	74.3

READINGS OF THE STANDARD AIR THERMOMETER: — (*Concluded*).

DATE.	July.			August.			September.			October.			November.			December.		
	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.	7 A. M.	12 M.	5 P. M.
1	74.	84.	82.	69.	80.	78.	59.	56.	55.	47.	51.	51.	49.	69.	63.	24.	40.	34.
2	73.	75.	67.	68.	81.	82.	51.	66.	71.	47.	56.	55.	69.	61.	58.	27.	36.	32.
3	55.	64.	63.	71.	81.	82.	62.5	79.	80.5	50.	53.	52.	46.	55.	53.	31.	39.	33.
4	58.	66.	70.	72.	82.	81.	65.	65.	66.	49.	60.	57.	40.	44.	42.	32.	34.	34.
5	64.	76.	78.	67.	84.	85.5	59.	55.	61.	52.	61.	62.	36.	42.	39.	38.	42.	38.
6	67.	73.	76.	65.	86.	87.	51.	70.	75.	46.	67.	64.	36.	52.	39.	35.	38.5	34.
7	64.	78.	79.	73.	88.	90.	56.	69.	63.	49.	70.	68.	33.	49.	49.	31.	34.	37.
8	69.	79.	79.	74.	94.5	91.	52.	71.	78.	48.	72.	71.	50.	57.	48.	26.	22.5	21.
9	65.	76.5	81.5	79.	82.	82.	58.	76.	69.	51.	75.	76.	32.	46.	44.	17.	26.	21.
10	69.5	85.	85.	69.	74.	75.	62.	63.	69.	53.	75.	72.	40.	49.	49.	22.	26.	26.
11	74.	86.	73.	61.5	74.	76.	60.	70.	65.	61.	65.	61.	46.	61.	64.	25.	26.	23.
12	68.	82.5	85.	59.	78.	80.	55.	66.	71.	48.	50.	47.	51.	72.	61.	18.	22.	21.
13	73.	77.	78.	63.	81.5	81.	63.	79.	81.	35.	39.	39.	47.	49.	49.	32.	35.	42.
14	72.	82.	76.	65.5	78.	81.	67.	89.	87.	40.	53.	51.	50.	59.	58.	35.	35.	34.
15	73.	86.	90.	65.	69.	63.5	70.	84.	78.	40.	46.	45.	52.	65.	52.	32.	33.	31.
16	71.	72.5	74.	67.	77.	73.	59.	69.	69.	39.	48.	44.	34.	39.	43.	27.	31.	26.
17	65.	75.	75.	59.	60.	58.	56.	75.	70.	41.	51.	46.	43.	40.	35.	25.	33.	28.
18	65.	74.	63.	60.	67.5	68.	58.	66.	64.	38.	40.	40.5	28.	27.	28.	23.	25.	26.
19	62.	70.	73.	66.	77.	81.	52.	66.	73.	37.	43.	40.	31.	37.	38.	21.	22.5	18.
20	63.	79.	78.	64.	74.	67.5	55.	66.	70.	35.	50.	44.	40.	55.	57.	20.	23.	20.
21	68.	80.	72.	61.	65.	64.	54.	72.	69.	44.	52.	52.	57.	60.	46.	21.	24.	22.
22	61.	69.	67.	64.	69.	77.	62.	77.	75.	50.	50.	49.	39.	52.	58.	20.	24.	23.
23	61.	64.	73.	66.	82.	81.	69.	81.	66.	39.	44.	41.	29.	28.	28.	27.	32.	31.
24	56.	70.	64.	67.	85.	83.	53.	63.	62.5	38.	38.	36.	23.	29.	29.	30.	31.5	30.
25	63.	77.	80.5	75.	90.	92.	50.	63.	59.	32.	45.	42.	24.	27.	30.	27.	28.	28.
26	77.	84.	82.	73.	81.	83.	51.	61.	58.	45.	55.	52.	36.	39.	36.	23.	26.	26.
27	66.	85.	86.	66.	78.5	79.	49.	53.	57.	49.	54.	48.	29.	42.	42.	19.	23.	19.
28	72.	86.	89.	62.	79.	81.	45.	58.	57.	35.	38.	36.	39.	55.	52.	14.	23.	21.
29	75.5	83.	87.	67.	77.	74.	48.	64.	66.	28.	36.	33.	33.	38.	32.	13.	12.	8.
30	73.	87.	85.5	53.	64.5	63.5	48.	55.	53.	30.	43.	42.	27.	38.	34.	7.	11.	9.
31	78.	83.	80.	55.	73.	71.	......	......	......	45.	68.	63.	......	......	......	8.	21.	17.
Monthly averages	67.6	77.7	77.1	66.	77.8	77.8	56.7	68. 2	67.9	43.3	53.2	51.	39.6	47.9	45.5	24. 2	28.4	26.1

SUMMARY OF MAXIMUM, MINIMUM AND STANDARD AIR THERMOMETERS FOR 1909.

	Maximum.	Minimum.	Standard.		
			7 A. M.	12 M.	5 P. M.
	Average.	Average.	Average.	Average.	Average.
January	35.9	19.5	25.4	29.9	29.
February	36.5	20.6	26.5	30.8	30.1
March	38.9	23.2	27.7	33.5	33.9
April	55.4	33.3	38.4	47.7	47.8
May	69.8	46.	55.2	63.7	64.
June	79.2	55.3	64.	74.6	74.3
July	81.6	57.6	67.6	77.7	77.1
August	83.	56.9	66.	77.8	77.8
September	76.2	50.8	56.7	68.2	67.9
October	56.4	39.1	43.3	53.2	51.
November	53.5	35.5	39.6	47.9	45.5
December	31.2	20.2	24.2	28.4	26.1

AVERAGE MONTHLY AND YEARLY TEMPERATURE SINCE 1882.

YEAR.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly av'ges.
1883	17.4	22.3	23.6	43.3	50.	66.6	67.4	65.6	56.3	46.6	39.1	27.5	43.8
1884	17.6	28.3	29.5	40.7	54.3	67.1	66.5	69.9	65.2	50.5	36.5	27.2	46.1
1885	20.6	11.4	18.8	41.2	54.3	63.6	69.7	65.0	58.3	49.2	39.3	27.8	43.3
1886	19.6	22.9	30.2	48.1	55.7	64.	68.	67.5	61.8	49.6	36.8	22.2	45.6
1887	20.2	23.2	26.3	41.1	62.5	65.7	75.6	66.5	57.7	47.0	37.6	27.6	45.9
1888	16.4	22.8	24.6	40.8	54.3	66.5	66.8	68.	62.2	43.9	39.4	29.3	44.6
1889	29.1	18.1	33.9	45.1	58.4	65.3	70.2	66.	60.5	44.	40.3	35.2	47.2
1890	31.2	30.9	28.8	44.2	52.3	67.1	69.5	67.7	60.1	49.3	37.6	21.4	46.7
1891	25.9	28.3	30.8	45.3	52.	66.4	66.4	68.5	66.2	48.3	38.4	35.5	47.7
1892	21.4	25.9	26.5	43.5	52.8	68.6	70.2	69.4	61.3	50.	35.9	25.2	45.9
1893	15.5	20.6	29.5	41.1	54.1	68.2	69.8	68.8	58.	52.	38.2	27.5	45.3
1894	29.7	20.9	38.9	44.1	55.5	67.8	74.2	66.8	64.8	52.7	36.	31.5	48.6
1895	21.8	16.9	26.9	44.4	59.	.....	.....	71.2	61.7	45.4	39.6	31.4	....
1896	22.4	24.1	24.4	49.3	62.	65.9	71.4	70.	60.2	56.5	42.9	27.1	48.0
1897	23.2	26.1	33.8	45.	55.4	62.3	73.6	67.6	62.3	52.6	39.7	29.2	47.6
1898	26.2	26.8	.....	43.2	57.	67.7	74.2	71.	65.9	52.1	37.9	27.9	....
1899	22.1	20.4	30.4	46.6	57.6	69.5	71.2	71.6	60.6	53.4	38.9	30.	47.7
1900	26.	22.6	23.6	43.5	56.7	68.4	72.6	74.1	66.1	57.9	41.1	28.7	48.5
1901	26.1	18.5	32.2	46.5	56.9	68.9	76.6	71.	64.	51.4	34.3	27.7	47.9
1902	23.2	22.2	39.5	46.6	56.1	63.2	71.2	67.6	63.6	43.1	46.3	25.7	47.4
1903	25.7	28.1	42.4	45.9	60.4	63.2	70.8	65.5	64.4	52.5	36.2	23.3	48.2
1904	18.9	23.1	30.9	41.4	60.3	67.8	70.	68.2	61.9	48.4	36.9	22.5	45.9
1905	19.8	18.9	33.1	44.8	57.5	66.4	71.8	68.7	63.7	52.4	37.6	32.	47.3
1906	32.5	26.1	27.6	46.4	57.5	68.2	71.4	72.8	67.3	51.2	37.9	26.1	48.8
1907	24.9	19.5	38.1	40.2	51.3	64.	71.2	68.4	64.4	47.9	38.7	31.8	46.7
1908	25.9	21.3	34.6	44.8	59.2	68.8	73.4	68.8	67.	52.9	40.	29.2	48.8
1909	27.7	28.6	31.	44.3	57.9	67.2	69.6	70.	63.5	47.7	44.5	25.7	48.1

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FROM 1883 TO 1909, INCLUSIVE.
(Highest and Lowest Record for each Month in Bold Face Type.)

	January.				February.				March.			
	Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883	18.	44.	11.	—9.	17.	48.	24.	—2.	19.	61.	9.	2.
1884	3.	49.	26.	—13.	7.	55.	29.	—3.	30.	54.	1.	—4.
1885	1.	61.	29.	—6.	10.	38.	11.	11.5	28.	48.	13.	—11.
1886	5.	52.5	13.	—18.7	9.	50.	27.	—11.	16.	58.	2.	—2.5
1887	24.	50.7	19.	—8.	9.	54.2	27.	—4.	3.	51.7	1 & 5	8.7
1888	2.	43.2	23.	—6.	21.	49.	10.	—7.	28.	57.	13.	0.
1889	18.	55.	20.	5.	23.	42.	4 & 24	—7.	28.	61.8	30.	18.5
1890	6.	67.	29.	9.	5.	64.5	11 & 21	9.5	13.	62.	8.	2.
1891	3.	46.	17.	4.	26.	56.8	15.	2.5	12.	57.	2.	4.5
1892	3.	48.	10.	—5.	15.	44.	6.	2.8	27.	52.2	4.	6.
1893	29.	46.	11.	—6.	15.	47.4	5.	—1.	24.	54.	5.	9.
1894	5.	59.	13.	11.	20.	47.6	27.	—8.5	18.	73.	26.	15.
1895†	7.	45.	19.	4.	25.	46.	8.	—14.	25.	52.	5 & 16	12.
1896	30.	44.	6.	—16.5	29.	49.	17.	—21.	31.	56.5	24.	—2.
1897	5.	58.	20.	—3.5	18.	49.5	1 & 27	5.5	21.	64.	1.	—1.
1898	13.	57.	30 & 31	—4.	12.	56.5	2 & 3	—2.	11.	*65.	2.	17.5
1899	5.	59.	12.	—4.	21.	52.5	11.	—8.	13.	63.	21.	13.
1900	23.	56.	1.	2.	14.	57.	27.	0.	10.	46.	12.	—3.
1901	16.	48.	20.	—2.	16.	36.	24.	—2.5	24.	67.	6.	—1.
1902	3.	44.	28.	2.	28.	52.	6.	—3.	12.	66.5	19.	14.
1903	3.	48.	9.	—2.	28.	62.5	18.	—4.	19.	78.5	1 & 2	19.
1904	23.	48.	19.	—14.	7.	58.	16.	—18.	26.	58.	4.	8.
1905	1.	49.	26.	—2.	20.	45.	5 & 14	—6.	29.	82.	5.	1.
1906	21.	71.	9.	4.	24.	64.	6 & 7	—7.	27.	51.	25.	2.
1907	6.	53.	24.	—18.	2.	47.	12 & 18	—4.	29.	83.	7.	—1.
1908	22.	45.	31.	—9.	15.	53.	5.	—14.	28.	73.	1.	8.
1909	24.	64.	19.	—7.	5.	52.	1.	—1.	10.	52.	5.	5.

*Maximum for first eleven days only. Record incomplete. †From data given by Mr. Edgar Parker. Station record not available.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FROM 1883 TO 1909, INCLUSIVE — (*Continued*).
(Highest and Lowest Record for each Month in Bold Face Type.)

	April				May				June			
	Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883	16.	75.	1.	19.	11.	87.	1 & 14	31.	7.	86.5	2.	42.
1884	28.	74.	1.	23.	24.	88.	30.	32.	25.	90.5	15.	41.
1885	24.	84.5	10.	20.5	18.	81.7	3.	27.5	14.	86.5	23.	41.5
1886	24.	80.5	4.	22.	23.	79.5	17 & 18	37.2	14.	86.2	1.	42.2
1887	11.	75.7	1.	17.2	23.	88.2	14.	37.5	17.	89.2	15.	47.7
1888	29.	82.5	8.	19.	13.	79.8	3.	29.	23.	94.1	4.	40.
1889	20.	84.	1.	26.	18.	91.8	29.	32.	22.	85.	5.	46.
1890	13.	78.8	1 & 19	23.	4.	80.7	2.	30.	30.	85.6	8.	44.8
1891	28.	81.4	7.	21.	11.	85.5	4.	29.5	16.	95.	6.	40.
1892	6.	78.	17.	25.5	31.	78.	9.	34.2	14.	92.	11.	45.8
1893	13.	75.3	26.	25.	25.	88.	9.	35.	21.	94.	1.	44.
1894	21.	71.3	2.	20.	2.	85.4	14.	32.6	23.	91.6	6.	39.
1895*	30.	80.	3.	28.	31.	92.	13 & 21	36.	3.	96.	7.	54.
1896	17.	87.	4 & 5	19.	11.	87.5	7 & 20	40.	21.	89.	3.	41.
1897	26.	82.	20.	19.	24.	80.	8.	32.5	24 & 25	87.5	2.	42.
1898	14 & 18	69.	5.	18.	29.	79.	6.	34.	9.	90.	16.	40.
1899	30.	82.	3.	23.	2.	87.5	15.	32.5	6 & 24	93.	11.	41.5
1900	30.	†73.5	9	†22.	15 & 16	88.5	7.	27.	25.	93.	10.	45.
1901	28.	78.	12.	28.	23.	78.	16.	36.	27, 28 & 29	95.5	2.	42.
1902	22.	87.	5.	25.	22.	90.	11.	26.	3.	85.	6.	38.
1903	30.	86.	5.	21.	19.	89.	2.	24.	30.	86.5	1.	39.
1904	24.	67.5	14.	16.	25.	88.	12.	31.5	5, 24 & 25	89.	12 & 17	45.
1905	27 & 28	75.	16.	23.	3.	82.	2.	29.5	19.	90.	1.	40.
1906	19.	74.	2.	25.	24.	88.5	11 & 21	30.	8.	92.	12.	37.
1907	29.	73.	2.	19.	14.	85.	2 & 11	28.	18.	94.	3.	41.
1908	27.	78.	4.	18.	29.	90.	1, 4 & 5	31.	19.	92.	12.	43.
1909	19.	75.	11.	12.	31.	78.	2 & 3	33.	28.	90.	8.	43.

*From data given by Mr. Edgar Parker. Station record not available. †Thermometers broken. Record not taken from April 19 to 24, inclusive.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FROM 1883 TO 1909, INCLUSIVE — (*Continued*).
(Highest and Lowest Record for each Month in Bold Face Type.)

	July.				August.				September.			
	Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883	23.	86.	1.	46.	23.	92.	15.	46.	17.	80.	11.	37.
1884	2.	87.5	15.	50.5	20.	95.	25.	44.	5.	94.	14.	36.
1885	18.	90.5	12.	46.5	1.	89.	28.	45.	27.	83.7	24.	40.
1886	7.	95.	1.	45.2	30.	91.5	6.	47.7	11.	89.5	22.	40.
1887	3.	95.5	11.	58.7	3.	88.5	8.	46.	22.	81.7	27.	37.2
1888	5.	89.8	16.	47.	9.	92.6	23.	48.3	1 & 10	83.	7.	40.
1889	11.	90.7	6.	50.5	31.	86.7	16 & 17	50.3	4.	84.	22, 23 & 29	40.
1890	9.	94.5	24.	46.5	4.	96.2	24.	46.0	8.	83.6	25.	35.5
1891	14.	92.	31.	46.	12.	92.	29.	46.5	26.	92.8	30.	43.
1892	29.	96.3	2.	46.4	10.	95.5	28.	49.	26.	88.	20.	39.
1893	26.	95.5	24.	48.4	11.	94.5	13.	49.	5.	80.	26.	37.4
1894	21.	97.	10.	49.6	25.	93.	27.	45.3	4.	90.	26.	33.
1895*	8.	94.	11.	52.	11.	88.	22.	44.	4.	94.	15 & 30	42.
1896	3.	94.	18.	49.	6 & 7	96.	29.	44.	12.	95.	23.	36.
1897	11.	97.	15.	57.	15.	87.5	21.	46.	11.	98.	21.	37.5
1898	4.	96.5	12.	40.	24.	90.5	28.	47.	4.	94.	21.	40.5
1899	4.	97.5	1.	50.	20.	97.5	15.	44.5	4.	92.	15 & 30	38.
1900	17.	96.	1.	50.	11.	97.	2.	51.	12.	95.	19.	37.
1901	1.	97.5	20.	54.5	22.	90.	5.	52.	6.	89.	26.	36.
1902	14 & 27	90.	1.	53.	31.	90.	13.	47.	1.	90.	15.	38.
1903	9.	94.	15.	50.	18.	85.5	8 & 14	45.	14.	90.	29.	35.
1904	19.	93.	3.	49.	25.	89.5	19.	45.	3.	88.	23.	33.
1905	18.	92.	22.	48.5	10.	93.	27.	41.	30.	88.5	26.	36.
1906	20, 22 & 23	89.	25.	50.	5.	93.	16.	47.	18.	91.5	25.	38.
1907	16.	90.	3 & 5	50.	12.	96.5	19.	41.5	20.	90.	27.	39.
1908	6, 11 & 30	94.	9.	52.	4.	95.	25.	46.	10.	92.	30.	37.
1909	15.	92.	4.	42.	8.	98.	31.	32.	14.	93.	2 & 6	35.

*From data given by Mr. Edgar Parker. Station record not available.

MONTHLY MAXIMUM AND MINIMUM TEMPERATURE FROM 1883 TO 1909, INCLUSIVE — (*Concluded*).

(Highest and Lowest Record for each Month in Bold Face Type.)

	October.				November.				December.			
	Max.		Min.		Max.		Min.		Max.		Min.	
	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.	Date.	Temp.
1883	11.	78.	17.	25.	22.	70.	17.	13.	10.	43.	23.	— 7.5
1884	5.	84.2	27.	23.	11.	62.	25.	15.	31.	55.5	20.	**—15.5**
1885	1.	79.	31.	25.	8 & 13	68.	28.	18.	24.	53.	9.	4.
1886	10.	76.7	17.	27.5	3.	68.2	28.	17.	11 & 25	46.	6.	—6.
1887	9.	78.5	31.	21.2	28.	68.	30.	15.	12.	54.7	2.	—3.
1888	6.	62.7	22.	29.	1 & 3	73.	23.	**8.**	27.	53.	22.	4.
1889	2.	68.7	24.	21.2	4.	61.7	17.	17.8	25.	60.5	4 & 5	8.
1890	5.	69.8	31.	32.	8.	65.4	28.	17.	1.	46.2	20.	3.
1891	4.	**89.4**	12 & 25	27.	1.	68.	29.	12.	5.	57.7	18.	7.
1892	1.	82.	2.	33.1	19.	60.	24.	18.	9.	49.2	27.	—3.7
1893	13.	76.	31.	25.	3.	62.2	27.	19.	26.	62.	14.	1.5
1894	1.	76.5	15.	33.	3.	65.	29.	12.	17.	59.	29.	—0.2
1895*	2.	72.	30.	28.	7.	68.	21.	19.	20 & 21	62.	13.	—2.
1896	30.	77.5	10 & 19	29.	19.	70.	21.	19.5	14.	58.	28.	2.
1897	16.	88.	10 & 18	30.	6.	65.	24.	16.5	12.	61.5	24.	2.
1898	1.	85.5	28.	31.	5.	63.	28.	16.	31.	54.	14.	3.
1899	15.	86.	3.	26.	19.	60.	14.	25.	12.	60.	31.	—1.
1900	6 & 7	89.	20.	28.	22.	70.	17.	19.	4.	55.	10 & 14	4.
1901	10 & 11	74.	28.	28.	1.	65.	27.	13.	14.	62.	18.	—1.
1902	19.	74.	10, 22 & 30	29.	14.	73.	29.	22.	2.	52.	9.	5.
1903	1.	73.	25 & 27	28.	4.	70.	26 & 27	12.	3.	46.	19.	—4.
1904	10.	81.	31.	22.	3.	65.	29.	9.	23.	53.	16.	—2.
1905	1.	85.	26.	**20.5**	12.	61.	14.	11.	29.	52.5	15.	1.
1906	5.	79.5	13 & 31	30.	19.	62.	30.	16.	6.	52.	8.	—1.
1907	7.	76.	31.	24.	1.	59.	16.	22.	30.	57.	22.	13.5
1908	18.	83.	21.	27.	26.	68.	5.	18.	1.	**64.**	23.	3.
1909	9.	82.5	29 & 30	27.	11.	**75.**	24.	21.	6.	45.	30.	1.

*From data given by Mr. Edgar Parker. Station record not available.

YEARLY MAXIMUM AND MINIMUM TEMPERATURES FROM 1883 TO 1909, INCLUSIVE.

(Highest and Lowest Record in Bold Face Type.)

	Maximum for Each Year.		Minimum for Each Year.	
	Date.	Temp.	Date.	Temp.
1883	Aug. 23	92.	Jan. 11	—9.
1884	Aug. 20	95.	Dec. 20	—15.5
1885	July 18	90.5	Feb. 11	—11.5
1886	July 7	95.	Jan. 13	—18.7
1887	July 3	95.5	Jan. 19	—8
1888	June 23	94.1	Feb. 10	—7
1889	May 18	91.8	Feb. 4 and 24	—7
1890	Aug. 4	96.2	Mar. 8	2
1891	June 16	95.	Feb. 15	2.5
1892	July 29	96.3	Jan. 10	—5.
1893	July 26	95.5	Jan. 11	—6.
1894	July 21	97.	Feb. 27	—8.5
1895*	June 3	96.	Feb. 8	—14.
1896	Aug. 6 and 7	96.	Feb. 17	—21.
1897	Sept. 11	98.	Jan. 20	—3.5
1898	July 4	96.5	Jan. 30 and 31	—4.
1899	July 4 and Aug. 20	97.5	Feb. 11	—8.
1900	Aug. 11	97.	Feb. 27	0.
1901	July 1	97.5	Feb. 24	2.5
1902	May 22, July 14 and 27, August 31 and Sept 1	90.	Dec. 9	—5.
1903	July 9	94.	Feb. 18 and Dec. 19	—4.
1904	July 19	93.	Feb. 16	—18.
1905	Aug. 10	93.	Feb. 5 and 14	—6.
1906	Aug. 5	93.	Feb. 6 and 7	—7.
1907	Aug. 12	96.5	Jan. 24	—18.
1908	Aug. 4	95.	Feb. 5	—14.
1909	Aug. 8	98.	Jan. 19	—7.

*From data given by Mr. Edgar Parker. Station record not available.

PRECIPITATION BY RAINFALL ONLY BY MONTHS SINCE 1882.

YEARS.	Jan.	Feb.	March.	April.	May.	June.	July.	August	Sept.	Oct.	Nov.	Dec.	Total.
	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
1882	.....	.....	.....	.....	.....	3.69	2.42	2.37	1.25	0.62	1.22	0.55	......
1883	0.48	1.44	0.88	1.58	4.45	4.12	2.98	3.47	2.12	2.10	1.54	0.73	25.89
1884	1.83	2.01	2.54	0.83	2.49	2.01	2.33	1.44	3.17	1.67	1.01	0.97	22.30
1885	1.07	0.61	0.12	1.26	1.58	2.49	4.64	5.02	2.11	2.88	1.36	0.76	23.90
1886	1.13	0.95	1.13	4.13	1.92	2.92	4.41	2.86	2.31	1.39	3.48	1.24	27.87
1887	0.18	2.17	0.48	1.37	0.46	2.01	6.37	3.03	0.75	1.74	1.58	1.35	21.49
1888	0.78	1.04	1.43	3.09	2.79	3.88	0.99	4.02	2.73	3.47	2.02	1.24	27.48
1889	2.99	0.25	0.66	3.28	1.21	7.47	4.57	4.98	2.50	3.32	3.44	1.62	36.29
1890	2.16	1.45	2.16	2.20	5.49	5.26	1.07	4.34	5.81	4.54	2.40	....	......
1891	1.44	1.57	3.25	1.63	0.49	4.31	3.52	3.16	0.47	3.65	0.74	3.29	27.52
1892	0.57	0.88	0.55	0.67	4.04	3.95	1.89	4.77	1.12	1.34	2.67	0.72	23.17
1893	1.62	3.71	1.94	2.59	4.92	3.08	3.68	5.38	2.68	1.59	1.09	1.56	33.84
1894	2.21	2.71	1.36	2.43	7.03	1.77	1.50	1.22	4.64	3.59	0.43	0.47	29.36
1895	0.96	.....	0.29	1.33	2.88	.....	.....	2.66	0.94	0.72	2.31	2.49	......
1896	1.19	2.28	0.84	0.41	2.31	3.71	4.12	3.33	4.27	2.26	2.18	0.71	27.61
1897	0.64	0.21	2.12	1.90	2.19	3.16	5.28	1.27	2.36	0.73	2.53	1.39	23.78
1898	1.74	0.83	1.54	2.03	1.90	2.39	1.32	3.60	1.86	3.83	2.03	0.33	23.40
1899	0.37	0.30	1.22	1.12	1.69	1.71	4.15	1.05	2.23	2.69	1.36	1.46	19.35
1900	1.43	2.42	0.02	0.95	1.71	1.45	6.53	1.75	0.91	3.65	6.13	0.78	27.73
1901	0.72	.....	2.19	4.43	3.80	2.07	3.97	5.62	2.46	1.35	2.09	3.37	......
1902	0.86	0.66	1.94	1.92	2.84	4.33	5.25	2.41	2.88	2.32	0.74	0.74	26.89
1903	1.81	1.11	5.60	2.60	0.23	7.77	4.86	7.21	1.30	4.19	1.63	0.38	38.69
1904	0.80	1.03	2.41	1.67	4.04	3.37	5.73	2.56	3.26	2.06	0.26	1.42	28.61
1905	0.40	0.27	1.09	2.05	2.01	8.78	3.39	5.44	1.90	3.69	1.32	1.84	32.38
1906	1 46	0.53	1.60	2.08	4.24	5.31	2.37	3.68	2.16	3.56	1.40	1.54	29.93
1907	1.89	0.03	1.14	2.42	1.82	2.34	2.86	1.35	2.73	3.48	2.78	1.89	24.73
1908	0.68	1.12	1.24	3.28	3.57	1.96	4.72	1.79	1.66	2.73	0.88	0.43	24.06
1909	0.94	1.68	1.35	3.20	2.83	2.17	2.04	2.21	2.22	1.18	0.56	0.49	20.87

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